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(54) **INSPECTION SYSTEM AND INSPECTION METHOD**

(57) According to one arrangement, an inspection system includes a first measurement unit (22a) for measuring a target, a first determination unit (24a) for making a first determination on whether the target includes a predetermined object using a first machine learning model (26a) based on a measurement result by the first measurement unit (22a), a second measurement unit (22b) for measuring the target, a second determination unit (24b) for making a second determination on whether the target includes the predetermined object based on a measurement result by the second measurement unit (22b), and a processing unit (12) for generating first update data of the first machine learning model (26a) based on the second determination.

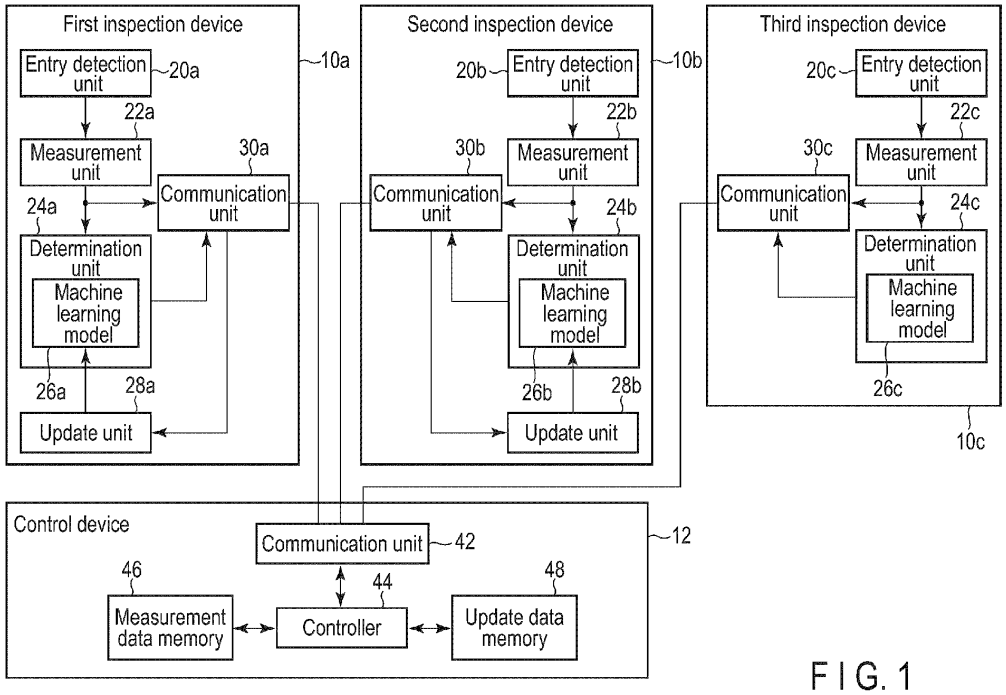


FIG. 1

EP 4 435 671 A1

Description

FIELD

[0001] The present disclosure relates to an inspection system and an inspection method.

BACKGROUND

[0002] An inspection system including a plurality of inspection devices that inspect belongings of the inspection target has been proposed. The plurality of inspection devices perform inspection in stages. Each of the plurality of inspection devices measures information in order to determine different items related to a predetermined object (here, a handgun).

BRIEF DESCRIPTION OF THE DRAWINGS

[0003]

FIG. 1 is a diagram for describing an example of an inspection system according to an arrangement.
FIG. 2 is a diagram for explaining an example of a machine learning model according to the arrangement.
FIG. 3 is a diagram for explaining an example of data stored in a measurement data memory according to the arrangement.
FIG. 4 is a diagram for describing an example of update data according to the arrangement.
FIG. 5 is a flowchart for explaining a first half of an example of processing of the inspection device according to the arrangement.
FIG. 6 is a flowchart for explaining a second half of an example of processing of the inspection device according to the arrangement.
FIG. 7 is a diagram for describing a first application example of an inspection system according to the arrangement.
FIG. 8 is a diagram for describing a second application example of an inspection system according to the arrangement.
FIG. 9 is a flowchart for explaining an example of processing of a control device according to the arrangement.
FIG. 10 is a diagram for describing a modification of the inspection system according to the arrangement.
FIG. 11 is a diagram for describing an example of arrangement of the inspection devices according to the arrangement.
FIG. 12 is a diagram for describing an example of a detailed configuration of each of first, second, and third inspection devices according to the arrangement.
FIG. 13 is a block diagram for explaining an example of a measurement unit according to the arrangement.
FIG. 14A is a diagram for describing an example of a waveform of a chirp signal according to the arrangement.
FIG. 14B is a diagram for describing an example of a waveform of a chirp signal according to the arrangement.
FIG. 15A is a diagram for explaining an example of a received signal according to the arrangement.
FIG. 15B is a diagram for explaining an example of a received signal according to the arrangement.
FIG. 15C is a diagram for explaining an example of a received signal according to the arrangement.
FIG. 16A is a diagram for explaining an example of the reflection intensity distribution according to the arrangement.
FIG. 16B is a diagram for explaining an example of the reflection intensity distribution according to the arrangement.
FIG. 16C is a diagram for explaining an example of the reflection intensity distribution according to the arrangement.

DETAILED DESCRIPTION

[0004] Various arrangements will be described hereinafter with reference to the accompanying drawings.

[0005] The disclosure is merely an example and is not limited by contents described in the arrangements described below. Modification which is easily conceivable by a person of ordinary skill in the art comes within the scope of the disclosure as a matter of course. In order to make the description clearer, the sizes, shapes, and the like of the respective parts may be changed and illustrated schematically in the drawings as compared with those in an accurate representation. Constituent elements corresponding to each other in a plurality of drawings are denoted by like reference numerals and their detailed descriptions may be omitted unless necessary.

[0006] According to one arrangement, an inspection system includes a first measurement unit configured to measure a target, a first determination unit configured to make a first determination on whether the target includes a predetermined object using a first machine learning model based on a measurement result by the first measurement unit, a second measurement unit configured to measure the target, a second determination unit configured to make a second determination on whether the target includes the predetermined object based on a measurement result by the second measurement unit, and a processing unit configured to generate first update data of the first machine learning model based

on a result of the second determination and transmit the first update data to the first determination unit.

[0007] An inspection system includes a plurality of inspection devices. Each of the inspection devices can obtain a determination result using a machine learning model based on a measurement result. When the machine learning model is prepared for each of the inspection devices, a determination result by a certain inspection device may not match a determination result by another inspection device. It is assumed that the inspection system includes first and second inspection devices. The first inspection device determines "whether an inspection target possesses a metal object". The second inspection device determines "where and what the inspection target possesses". When the determination result by the first inspection device is "the inspection target has a metal object" and the determination result by the second inspection device is "the inspection target has a notebook in the left chest pocket", the "metal object" and the "notebook" do not match with each other. In this case, it is difficult for the inspection system to accurately identify the inspection target holding the handgun in the end. The purpose of the arrangements is to overcome such a problem.

[0008] FIG. 1 is a diagram for describing an example of an inspection system according to an arrangement. An inspection system related to security will be described as an arrangement of the inspection system. The inspection system is disposed in an area where many and unidentified persons exist, such as a station, a commercial facility, a concert hall, or an amusement park. Carrying predetermined objects, for example dangerous objects such as handguns, knives, and explosives, into this area is not permitted. Hereinafter, a handgun will be described as the predetermined object. The inspection system identifies an inspection target including a handgun. Here, "including" means, for example, being worn or being included in baggage. When the inspection system identifies an inspection target carrying a handgun, a person in charge carefully may examine the inspection target.

[0009] The inspection system includes a plurality of inspection devices. FIG. 1 illustrates an example of an inspection system including three inspection devices according to the first arrangement. The inspection system includes a first inspection device 10a, a second inspection device 10b, a third inspection device 10c, and a control device 12. The first inspection device 10a, the second inspection device 10b, and the third inspection device 10c are connected to the control device 12. The number of inspection devices may be two or three or more.

[0010] When a person in charge is present at the installation place of the inspection system, the person in charge guides the inspection target to the first inspection device 10a, the second inspection device 10b, and the third inspection device 10c in this order. As a result, the inspection target is inspected by the first inspection device 10a, the second inspection device 10b, and the third inspection device 10c in this order.

[0011] When the inspection system is installed in a place where there is a human flow such as a passage, the first inspection device 10a, the second inspection device 10b, and the third inspection device 10c are installed in order according to the flow of the inspection target. For example, when the inspection system is installed in a pedestrian passage, the first inspection device 10a is installed at the entrance of the passage, the third inspection device 10c is installed at the exit of the passage, and the second inspection device 10b is installed between the first inspection device 10a and the third inspection device 10c. Accordingly, the inspection target moving on the passage is inspected by the first inspection device 10a, the second inspection device 10b, and the third inspection device 10c in this order.

[0012] The first inspection device 10a includes an entry detection unit 20a, a measurement unit 22a, a determination unit 24a, an update unit 28a, and a communication unit 30a.

[0013] The entry detection unit 20a detects that an inspection target enters an inspection range of the first inspection device 10a. Examples of the entry detection unit 20a include a human sensor and a camera. When the entry detection unit 20a detects entry of an inspection target, the measurement unit 22a starts measurement and generates identification information (inspection target ID) of the inspection target.

[0014] The communication unit 30a transmits the inspection target ID to the control device 12. The control device 12 transmits the inspection target ID to the second inspection device 10b and the third inspection device 10c.

[0015] The measurement unit 22a obtains a first feature amount of the inspection target. Examples of the measurement unit 22a include a radar, a metal detector, a liquid detector, an X-ray diagnosis device, and a camera. The measurement unit 22a transmits the first measurement data indicating the first feature amount together with the inspection target ID to the determination unit 24a and the communication unit 30a. The measurement unit 22a may include a memory that temporarily stores the first measurement data.

[0016] The determination unit 24a includes a machine learning model 26a. The machine learning model 26a is a circuit that outputs a first determination result when given certain first measurement data. The determination result is referred to as a label. The machine learning model may be referred to as an artificial intelligence (AI) model. An example of a machine learning model is a convolution neural network. The machine learning model 26a is generated by measuring a large number of inspection targets by the measurement unit 22a and assigning one or more first labels to each of first measurement data. The first label is input by an operator.

[0017] FIG. 2 is a diagram for explaining an example of the machine learning model 26a according to the first arrangement. The machine learning model 26a includes a plurality of first measurement data M1, M2, M3, ..., and a plurality of first labels L1, L2, L3, ... The machine learning model 26a is data indicating a correspondence relationship between the first measurement data and the first label. FIG. 2 illustrates an example in which the first measurement data M1, M2,

M3, ... corresponds to the first labels L1, L2, L3, ..., respectively. The number of first labels corresponding to one piece of first measurement data may be plural.

[0018] Returning to the description of FIG. 1, the first measurement data is input to the determination unit 24a. The determination unit 24a makes the first determination using the machine learning model 26a. The first determination is to determine one or more first labels corresponding to the first measurement data. An example of the first determination is "whether the inspection target possesses a metal object". The determination unit 24a outputs a single first label "metal object possessed" or "metal object not possessed" for one piece of first measurement data. The first label is part of the final label of the inspection system. Therefore, assuming that the final reliability of the label of the inspection system is 1, the reliability of the first label is 1 or less.

[0019] The determination unit 24a may determine the first label by performing an arithmetic process on the first measurement data without using the machine learning model 26a.

[0020] In a case where a person in charge is present at the installation place of the inspection system, the determination unit 24a may notify the person in charge of the information about the first label by text display or sound output using a display device or a speaker (not illustrated). In a case where a person in charge is not present at the installation place of the inspection system, the determination unit 24a may transmit the first label to an electronic device carried by the person in charge or a display device in a management room where the person in charge waits via the communication unit 30a. The determination unit 24a may include a memory that temporarily stores the first label.

[0021] The communication unit 30a transmits the first measurement data together with the inspection target ID to the control device 12. The communication unit 30a receives the first update data transmitted from the control device 12. The communication unit 30a transmits the first update data to the update unit 28a. The update unit 28a updates (may be referred to as relearning) the machine learning model 26a based on the first update data. The correspondence relationship between the first measurement data M1, M2, M3, ..., and the plurality of first labels L1, L2, L3, ... is changed by the update of the machine learning model 26a. After updating the machine learning model 26a, the measurement unit 22a may measure the inspection target again, and the determination unit 24a may make the first determination again based on the measurement data measured again. After updating the machine learning model 26a, the measurement unit 22a may not measure again the inspection target, and the determination unit 24a may make the first determination again based on the already obtained first measurement data.

[0022] The second inspection device 10b includes an entry detection unit 20b, a measurement unit 22b, a determination unit 24b, an update unit 28b, and a communication unit 30b.

[0023] The entry detection unit 20b, the measurement unit 22b, the determination unit 24b, the update unit 28b, and the communication unit 30b respectively correspond to the entry detection unit 20a, the measurement unit 22a, the determination unit 24a, the update unit 28a, and the communication unit 30a.

[0024] When the entry detection unit 20b detects that the inspection target which has been inspected by the first inspection device 10a enters the inspection range of the second inspection device 10b, the measurement unit 22b starts measurement.

[0025] Examples of the measurement unit 22b include a radar, a metal detector, a liquid detector, an X-ray diagnosis device, and a camera.

[0026] The measurement unit 22b may obtain the first feature amount of the inspection target, as in the measurement unit 22a. The measurement unit 22a may obtain the first feature amount at the first level of detail, and the measurement unit 22b may obtain the first feature amount at the second level of detail. The second level of detail may be higher than the first level of detail. The inspection device 10b inspects the target more precisely than the inspection device 10a. The communication unit 30b receives the inspection target ID from the control device 12. The measurement unit 22b transmits the second measurement data indicating the first feature amount to the determination unit 24b and the communication unit 30b. The measurement unit 22b may include a memory that temporarily stores the second measurement data.

[0027] When the measurement units 22a and 22b are radars, each of the measurement units 22a and 22b transmits an electromagnetic wave to the inspection target and receives a reflected wave from the inspection target. The reflectance of the electromagnetic wave to the metal object is higher than the reflectance of the electromagnetic wave to the skin. Each of the measurement units 22a and 22b obtains an image indicating the distribution of the reflectance of the electromagnetic wave at each point of the inspection target. The level of detail is related to the resolution of the image. The resolution of the image obtained by the measurement unit 22b may be higher than that of the image obtained by the measurement unit 22a. The resolution of the image depends on the number of radar antennas composing the image.

[0028] Alternatively, unlike the measurement unit 22a, the measurement unit 22b may obtain the second feature amount of the inspection target. The second feature amount is different from the first feature amount. The measurement unit 22a may obtain the first feature amount at the first level of detail, and the measurement unit 22b may obtain the second feature amount at the second level of detail. The second level of detail may be higher than the first level of detail. The measurement unit 22b may transmit the second feature amount as second measurement data to the determination unit 24b. Assuming that the measurement unit 22a is a radar and the measurement unit 22b is a metal detector, in a case where a metal object is identified, information (second feature amount) obtained by the metal detector has a higher

level of detail than an image (first feature amount) obtained by the radar.

[0029] The determination unit 24b includes a machine learning model 26b. As in the machine learning model 26a illustrated in FIG. 2, the machine learning model 26b is a circuit that outputs a second label when given certain second measurement data. The machine learning model 26b is generated by measuring a large number of inspection targets by the measurement unit 22b and assigning one or more second labels to each of second measurement data. The second label is input by the operator.

[0030] As in the first machine learning model 26a, also in the second machine learning model 26b, one second label may be assigned to one second measurement data, or a plurality of second labels may be assigned to one second measurement data.

[0031] The determination unit 24b makes the second determination using the machine learning model 26b. The second determination is to determine one or more second labels corresponding to the second measurement data. An example of the second determination is "what the inspection target possesses and where". The determination unit 24b outputs two second labels of "something like a smartphone" (what) and "left chest pocket" (where) with respect to one second measurement data. The second label is part of the final label of the inspection system. The reliability of the device is defined separately from the reliability of the first, second, and third labels. The reliability f(x) of the determination of "what is the object to be inspected" is defined by the product of the reliability of the label and the reliability of the device. Therefore, even when the reliability x3 of the third label is lower than the reliability x2 of the second label ($x2 > x3$), the reliability f(x3) of the determination may be higher than the reliability f(x2) of the determination ($f(x2) \leq f(x3) \leq 1.0$). Since the level of detail of the data obtained by the measurement unit 22b is higher than the level of detail of the data obtained by the measurement unit 22a, the reliability of the second label is higher than the reliability of the first label.

[0032] The determination unit 24b may determine the second label by performing an arithmetic process on the second measurement data without using the machine learning model 26b.

[0033] In a case where a person in charge is present at the installation place of the inspection system, the determination unit 24b may notify the person in charge of the information about the second label by text display or sound output using a display device or a speaker (not illustrated). In a case where a person in charge is not present at the installation place of the inspection system, the determination unit 24b may transmit the second label to an electronic device carried by the person in charge or a display device in a management room where the person in charge waits via the communication unit 30b. The determination unit 24b may include a memory that temporarily stores the second label.

[0034] The communication unit 30b transmits the second measurement data together with the inspection target ID to the control device 12. The communication unit 30b receives the second update data transmitted from the control device 12. The communication unit 30b transmits the second update data to the update unit 28b. The update unit 28b updates the machine learning model 26b based on the second update data. The correspondence relationship between the second measurement data and the second label is changed by the update of the machine learning model 26b. After updating the machine learning model 26b, the measurement unit 22b may measure the inspection target again, and the determination unit 24b may make the second determination again based on the measurement data measured again. After updating the machine learning model 26b, the measurement unit 22b may not measure again the inspection target, and the determination unit 24b may make the second determination again based on the already obtained second measurement data.

[0035] The third inspection device 10c includes an entry detection unit 20c, a measurement unit 22c, a determination unit 24c, and a communication unit 30c. The entry detection unit 20c, the measurement unit 22c, the determination unit 24c, and the communication unit 30c respectively correspond to the entry detection unit 20a (or entry detection unit 20b), the measurement unit 22a (or measurement unit 22b), the determination unit 24a (or determination unit 24b), the update unit 28a (or update unit 28b), and the communication unit 30a (or communication unit 30b).

[0036] When the entry detection unit 20c detects that the inspection target which has been inspected by the second inspection device 10b enters the inspection range of the third inspection device 10c, the measurement unit 22c starts measurement.

[0037] Examples of the measurement unit 22c include a radar, a metal detector, a liquid detector, an X-ray diagnosis device, and a camera. In a case where the measurement unit 22c is a camera, when detecting that the inspection target reaches the inspection area of the third inspection device 10c, the entry detection unit 20c prompts the inspection target to take out the belongings from the pocket and place the belongings on the imaging table in front of the measurement unit 22c using the display device or the speaker.

[0038] The measurement unit 22c may obtain the first feature amount of the inspection target, as in the measurement units 22a and 22b. The measurement unit 22a may obtain the first feature amount at the first level of detail, the measurement unit 22b may obtain the first feature amount at the second level of detail, and the measurement unit 22c may obtain the first feature amount at the third level of detail. The third level of detail may be higher than the first level of detail and the second level of detail. Communication unit 30c receives the inspection target ID from the control device 12. The measurement unit 22c transmits the first feature amount as third measurement data to the determination unit 24c and the communication unit 30c. The measurement unit 22c may include a memory that temporarily stores the third

measurement data.

[0039] When the measurement units 22a, 22b, and 22c are radars, each of the measurement units 22a, 22b, and 22c transmits an electromagnetic wave to an inspection target and receives a reflected wave from the inspection target. The reflectance of the electromagnetic wave to the metal object is higher than the reflectance of the electromagnetic wave to the skin. Each of the measurement units 22a, 22b, and 22c obtains an image indicating the distribution of the reflectance of the electromagnetic wave at each point of the inspection target. The level of detail is related to the resolution of the image. The resolution of the image obtained by the measurement unit 22b may be higher than that of the image obtained by the measurement unit 22a. The resolution of the image obtained by the measurement unit 22c may be higher than that of the image obtained by the measurement unit 22b.

[0040] Alternatively, the measurement unit 22c may obtain the third feature amount of the inspection target, unlike the measurement units 22a and 22b. The third feature amount is different from the first feature amount and the second feature amount. The measurement unit 22a may obtain the first feature amount at the first level of detail, the measurement unit 22b may obtain the second feature amount at the second level of detail, and the measurement unit 22c may obtain the third feature amount at the third level of detail. The third level of detail may be higher than the first level of detail and the second level of detail. Assuming that the measurement unit 22a is a radar, the measurement unit 22b is a metal detector, and the measurement unit 22c is a camera, when the metal object is identified, an image (third feature amount) by the camera that captures the belongings has a higher level of detail than an image (first feature amount) obtained by the radar and information (second feature amount) obtained by the metal detector. The measurement unit 22c may transmit the third feature amount as third measurement data to the determination unit 24c.

[0041] The determination unit 24c includes a machine learning model 26c. The machine learning model 26c is a circuit that outputs a third label when given certain third measurement data, as in the machine learning model 26a illustrated in FIG. 2 and the machine learning model 26b. The machine learning model 26c is generated by measuring a large number of inspection targets by the measurement unit 22c and assigning a large number of third labels to a large number of third measurement data. The third label is input by the operator. As in the first machine learning model 26a and the second machine learning model 26b, also in the third machine learning model 26c, one third label may be assigned to one piece of third measurement data, or a plurality of third labels may be assigned to one piece of third measurement data. Since the third inspection device 10c is the last inspection device, the third label is the final label of the inspection system. The third label includes the first label and the second label.

[0042] The determination unit 24c makes the third determination based on the third measurement data using the machine learning model 26c. The third determination is to determine one or more third labels corresponding to the third measurement data. Examples of the third determination include "whether the inspection target possesses a metal object or nor" and "what and where the inspection target possesses". The determination unit 24c outputs three third labels of "metal object possessed" or "metal object not possessed", "smartphone" (what), and "left chest pocket" (where). In a case where the measurement unit 22c is a camera, it is possible to determine what (smartphone) the belongings are by performing an image analysis on the captured image of the belongings. The reliability f(x3) of the third determination is 1, which is higher than the reliabilities f(x1) and f(x2) of the first and second determinations.

[0043] The determination unit 24c may determine the third label by performing an arithmetic process on the third measurement data without using the machine learning model 26c.

[0044] In a case where a person in charge is present at the installation place of the inspection system, the third determination unit 24c may notify the person in charge of the information about the third label by text display or sound output using a display device or a speaker (not illustrated). In a case where a person in charge is not present at the installation place of the inspection system, the determination unit 24c may transmit the third label to an electronic device carried by the person in charge or a display device in a management room where the person in charge waits via the communication unit 30c. When the third label indicates that "the inspection target has a handgun in the left chest pocket", a person in charge may carefully check the inspection target. The third determination unit 24c may include a memory that temporarily stores the third label.

[0045] Determination unit 24c transmits the third label to the communication unit 30c. The communication unit 30c transmits the third measurement data and the third label corresponding thereto to the control device 12 together with the inspection target ID.

[0046] The control device 12 includes a communication unit 42, a controller 44, a measurement data memory 46, and an update data memory 48.

[0047] FIG. 3 is a diagram for explaining an example of data stored in the measurement data memory 46 according to the arrangement. The controller 44 writes the first measurement data M10, M11, M12, ... transmitted from the first inspection device 10a, the second measurement data M20, M21, M22, ... transmitted from the second inspection device 10b, and the third measurement data M30, M31, M32, ... transmitted from the third inspection device 10c, and the third label into the measurement data memory 46 for each inspection target ID. The third label includes the first label and the second label.

[0048] The third label with the inspection target ID = 00000000 includes a first label L30a and second labels L30b and

L30c. The third label with the inspection target ID = 00000001 includes a first label L31a and second labels L31b and L31c. The third label with the inspection target ID = 00000002 includes a first label L32a and second labels L32b and L32c.

[0049] FIG. 4 is a diagram for describing an example of update data stored in the update data memory 48 according to the arrangement. The update data includes a large number of pairs of measurement data and teacher labels.

[0050] The reliability of the label of the determination unit 24a and the reliability of the label of the determination unit 24b may decrease. An example of the case of the decrease includes a change in the installation environment of the inspection devices 10a and 10b after generation of the machine learning models 26a and 26b. In this case, the first and second measurement data themselves change so that the machine learning models 26a and 26b cannot output a correct label for the measurement data. In order to maintain the reliability of the labels of the determination units 24a and 24b, it is preferable to update the machine learning models 26a and 26b based on the actual measurement data.

[0051] The actual measurement data is stored in the measurement data memory 46. Since the third label has reliability of 1, the third label includes an accurate first label and an accurate second label. When the machine learning models 26a and 26b are updated using the third label, the reliability of determination by the determination units 24a and 24b can be maintained. The controller 44 associates the first labels L30a, L31a, L32a, ... among the third labels in the measurement data memory 46 as first teacher labels with the first measurement data M10, M11, M12, ... to create the first update data. The controller 44 associates the second labels L30b, L30c; L31b, L31c; L32b, L32c; ... among the third labels in the measurement data memory 46 as second teacher labels with the second measurement data M20, M21, M22, ... to create the second update data.

[0052] At the update timing, the controller 44 transmits the first and second update data to the update units 28a and 28b, respectively. The update units 28a and 28b respectively update the machine learning models 26a and 26b based on the update data. The update unit 28a changes the first labels L1, L2, L3, ... of the machine learning model 26a as illustrated in FIG. 2 to the first teacher labels L30a, L31a, L32a, ... included in the first update data. The update unit 28b changes the first labels of the machine learning model 26b to the first teacher labels included in the second update data. As a result, the correspondence relationship between the measurement data and the label is updated, and the determination units 24a and 24b are more likely to make a correct determination.

[0053] FIGS. 5 and 6 are flowcharts for explaining an example of processing of the inspection devices 10a, 10b, and 10c of the inspection system according to the arrangement. FIG. 7 is a diagram for describing a first application example of the inspection system according to the arrangement. FIG. 8 is a diagram for describing a second application example of the inspection system according to the arrangement. In the first and second application examples, it is assumed that the measurement unit 22a is a first radar, the measurement unit 22b is a second radar, the resolution of the second radar is higher than the resolution of the first rater, and the measurement unit 22c is a camera. In the first application example (FIG. 7), the first label is "metal object possessed", the second labels are "smartphone" and "left chest pocket", and the third labels are "metal object possessed", "smartphone", and "left chest pocket". In the second application example (FIG. 8), the first label is "metal object possessed", the second labels are "smartphone" and "left chest pocket", and the third labels are "metal object not possessed", "notebook", and "left chest pocket".

[0054] The entry detection unit 20a determines whether the inspection target enters the inspection range of first inspection device 10a (S10). When the entry detection unit 20a detects the entry of the inspection target (S10: YES), the first measurement unit (radar) 22a irradiates the inspection target with an electromagnetic wave (S12). The measurement unit 22a receives the reflected wave of the electromagnetic wave from the inspection target (S14). The measurement unit 22a generates an image signal indicating the reflection intensity of each point of the inspection target based on the received signal. The measurement unit 22a transmits the image signal as the first measurement data to the determination unit 24a and the communication unit 30a together with the inspection target ID (S16).

[0055] The determination unit 24a uses the machine learning model 26a to determine whether the inspection target possesses a metal object based on the image signal (first determination) (S18). In both the first application example and the second application example, the first label is "metal object possessed".

[0056] The communication unit 30a transmits the first measurement data to the control device 12 (S20).

[0057] The inspection system includes three inspection devices 10a, 10b, and 10c, but all the three inspection devices 10a, 10b, and 10c do not necessarily perform inspection. Depending on the installation location of the inspection system, there may be a date and time and a time zone in which the highest priority is given to not disturbing the flow of people. Depending on the purpose of the inspection, the inspection by the first inspection device 10a or up to the second inspection device 10b may be sufficient. Therefore, there is a case where only the first inspection device 10a performs the inspection or a case where the third inspection device 10c does not perform the inspection. The control device 12 can select whether to operate the second inspection device 10b and the third inspection device 10c depending on the installation situation.

[0058] The control device 12 transmits an ON signal or an OFF signal to the second inspection device 10b and the third inspection device 10c.

[0059] The second inspection device 10b determines whether an ON signal or an OFF signal from the control device 12 is received (S22). When an OFF signal is received, the second inspection device 10b does not perform the inspection,

and the processing of the inspection system ends.

[0060] When receiving an ON signal, the entry detection unit 20b determines whether the inspection target enters the inspection range of the second inspection device 10b (S24). When the entry detection unit 20b detects the entry of the inspection target (S24: YES), the second measurement unit (radar) 22b irradiates the inspection target with an electromagnetic wave (S26). The measurement unit 22b receives the reflected wave of the electromagnetic wave from the inspection target (S28). The measurement unit 22b generates an image signal indicating the reflection intensity of each point of the inspection target to transmit the image signal to the determination unit 24b as the second measurement data (S30).

[0061] The determination unit 24b uses the machine learning model 26b to determine what and where the inspection target possesses based on the image signal (second determination) (S32). In both the first application example (FIG. 7) and the second application example (FIG. 8), the second label is "carry a smartphone in the left chest pocket".

[0062] The communication unit 30b transmits the second measurement data together with the inspection target ID to the control device 12 (S34).

[0063] The third inspection device 10c determines whether an ON signal or an OFF signal from the control device 12 is received (S36). When an OFF signal is received, the third inspection device 10c does not perform the inspection, and the processing of the inspection system ends.

[0064] When receiving an ON signal, the entry detection unit 20c determines whether the inspection target enters the inspection range of the third inspection device 10c (S38). When the entry detection unit 20c detects the entry of the inspection target (S38: YES), the third measurement unit (camera) 22c photographs the belongings on the imaging table (S40). When the inspection target enters the inspection range of the third inspection device 10c, the belongings are placed on the imaging table within the imaging range of the measurement unit 22c. The measurement unit 22c generates an image signal of the belongings to transmit the image signal as the third measurement data to the determination unit 24c and the communication unit 30c (S42) .

[0065] The determination unit 24c identifies the belongings of the inspection target using the machine learning model 26c based on the image signal (third determination) (S44). In the first application example (FIG. 7), it is assumed that the third labels (third determination results) are "metal object possessed" and "carry a smartphone in the left chest pocket". In the second application example (FIG. 8), it is assumed that the third labels are "metal object not possessed" and "carry a notebook in the left chest pocket".

[0066] The determination unit 24c transmits the third label or labels to the communication unit 30c (S46).

[0067] The communication unit 30c transmits the third measurement data and the third label or labels to the control device 12 together with the inspection target ID (S48).

[0068] Thereafter, the processing of the system ends. Although the measurement data are transmitted to the control device 12 at three steps S16, S34, and S48, the measurement data of the first inspection device 10a and the second inspection device 10b may be collectively transmitted when the measurement data of the third inspection device 10c is transmitted.

[0069] FIG. 9 is a flowchart for explaining an example of processing of the control device 12 of the inspection system according to the arrangement.

[0070] When the communication unit 42 receives the first measurement data and the inspection target ID, the controller 44 writes the first measurement data and the inspection target ID into the measurement data memory 46 (S60).

[0071] When the communication unit 42 receives the second measurement data and the inspection target ID, the controller 44 writes the second measurement data into the measurement data memory 46 (S62). The controller 44 writes the first measurement data and the second measurement data into the measurement data memory 46 in association with each other based on the inspection target ID.

[0072] When the communication unit 42 receives the third measurement data and the third labels, the controller 44 writes the third measurement data and the third labels into the measurement data memory 46 (S64). The controller 44 writes the first measurement data, the second measurement data, the third measurement data, and the third labels (metal object possessed, smartphone, left chest pocket) into the measurement data memory 46 in association with each other based on the inspection target ID.

[0073] The controller 44 generates first update data by associating the first label (metal object possessed) in the third labels with the first measurement data, and writes the first update data into the update data memory 48 (S66). The controller 44 generates second update data by associating the second labels (smartphone, left chest pocket) in the third labels with the second measurement data, and writes the second update data into the update data memory 48 (S68).

[0074] As illustrated in FIGS. 3 and 4, the controller 44 receives the first, second, and third measurement data for a large number of inspection targets, and generates a large number of first and second update data.

[0075] The controller 44 determines whether it is time to update the machine learning models 26a and 26b of the inspection devices 10a and 10b (S70). The controller 44 may be set to periodically perform the update after a lapse of a certain period of time, or may be set to perform the update when an environmental sensor (not illustrated) detects a change in an installation environment (temperature, humidity, etc.) of the system.

[0076] When it is determined that it is the time of update (S70: YES), the controller 44 transmits the first update data to the first inspection device 10a (S72). The controller 44 transmits the second update data to the second inspection device 10b (S74).

[0077] When it is determined that it is not the time of update (S70: NO), or after transmission of the second update data, the controller 44 ends the process.

[0078] When receiving the first and second update data, the inspection devices 10a and 10b update the machine learning models 26a and 26b using the update units 28a and 28b, respectively. In the first application example (FIG. 7), the first and second labels output by the determination units 24a and 24b match the third label or labels. Therefore, even when the machine learning models 26a and 26b are updated, the first and second labels do not change. In the second application example (FIG. 8), the first label is "metal object possessed", the third label is "metal object not possessed", and the first label does not match the third label. Part related to an object in the second label is a smartphone, part related to an object in the third label is a notebook, and part of the second label does not match part of the third label. When the machine learning models 26a and 26b are updated, the first label is changed to "metal object not possessed", and part related to an object in the second label is changed to "a notebook".

[0079] In this manner, by updating the machine learning model for obtaining the first and second labels based on the update data generated based on the third label, the reliability of the first and second labels is improved.

[0080] FIG. 10 is a diagram for describing a modification of the inspection system according to the arrangement. The inspection system according to the modification does not include the control device 12. A third inspection device 10d has the function of the control device 12. As in the third inspection device 10c, the third inspection device 10d includes the entry detection unit 20c, the measurement unit 22c, the determination unit 24c, the machine learning model 26c, and the communication unit 30c. The third inspection device 10d further includes the controller 44, the measurement data memory 46, and the update data memory 48. The first, second, and third inspection devices 10a, 10b, and 10d are connected to a network 14.

[0081] Each of the first and second inspection devices 10a and 10b transmits the first and second measurement data to the third inspection device 10d via the network 14. As in the control device 12, the controller 44 (the third inspection device 10d) writes the first and second measurement data into the measurement data memory 46, generates update data, and writes the update data into the update data memory 48. At the time of updating the machine learning models 26a and 26b, the communication unit 30c (the third inspection device 10d) transmits the first and second update data to the first and second inspection devices 10a and 10b via the network 14. Therefore, the inspection system according to the modification has the same effect as the inspection system according to the arrangement.

[0082] FIG. 11 is a diagram for describing an example of arrangement of inspection devices 10a, 10b, and 10c (or 10d) according to the arrangement. An inspection target 18 walks along the passage. The inspection devices 10a, 10b, and 10c (or 10d) are disposed along the passage in order in the traveling direction. The inspection target 18 is sequentially inspected by the first, second, and third inspection devices 10a, 10b, and 10c (or 10d) during walking. Here, it is assumed that each of the inspection devices 10a, 10b, and 10c (or 10d) includes a radar. The radar includes antennas 16 located on both sides of the passage. The number of antennas included in the radar of the inspection device 10a through which the inspection target 18 passes first is the smallest. The inspection time of the inspection device 10a is the shortest, while the reliability of the determination result is the worst. The number of antennas included in the radar of the inspection device 10c (or 10d) through which the inspection target 18 passes last is the largest. The inspection time of the inspection device 10c (or 10d) is the longest, while the reliability of the determination result is the best.

[0083] The inspection devices 10a, 10b, and 10c (or 10d) and the control device 12 are connected by a wireless LAN or a wired LAN. Examples of the wireless LAN are WiFi (registered trademark) and Bluetooth (registered trademark). As the wired LAN, a metal cable or an optical fiber may be used.

[0084] FIG. 12 is a diagram for describing an example of a detailed configuration of each of the first, second, and third inspection devices 10a, 10b, and 10c (or 10d) according to the arrangement. The first, second, and third inspection devices 10a, 10b, and 10c (or 10d) are referred to as an inspection device 10 in a case where it is not particularly necessary to distinguish them. The first, second, and third entry detection units 20a, 20b, and 20c are referred to as an entry detection unit 20 in a case where it is not particularly necessary to distinguish them. The first, second, and third measurement units 22a, 22b, and 22c are referred to as a measurement unit 22 in a case where it is not particularly necessary to distinguish them. The first, second, and third determination units 24a, 24b, and 24c are referred to as a determination unit 24 in a case where it is not particularly necessary to distinguish them. The first, second, and third machine learning models 26a, 26b, and 26c are referred to as a machine learning model 26 in a case where it is not particularly necessary to distinguish them. The first, second, and third update units 28a, 28b, and 28c are referred to as an update unit 28 in a case where it is not particularly necessary to distinguish them. The first, second, and third communication units 30a, 30b, and 30c are referred to as a communication unit 30 in a case where it is not particularly necessary to distinguish them. The inspection device 10 includes the entry detection unit 20, the measurement unit 22, the communication unit 30, a CPU 62, a storage 64, and a memory 66. The entry detection unit 20, the measurement unit 22, the communication unit 30, the storage 64, and the memory 66 are connected to a bus line of the CPU 62. The

measurement unit 22 includes an antenna 72 and a signal processing unit 74.

[0085] The antenna 72 may include at least one transmit/receive antenna, or may include at least one transmit antenna and at least one receive antenna. The transmit direction or the position of the transmit point of the electromagnetic wave of the antenna 72 can be mechanically changed by a mechanical scanning mechanism, or can be electronically changed by an electronic scanning circuit provided in the signal processing unit 74. The measurement unit 22 may include both a scanning mechanism and a scanning circuit.

[0086] The electromagnetic wave used in the radar includes an electromagnetic wave having a wavelength of 1 mm to 30 mm. An electromagnetic wave having a wavelength of 1 mm to 10 mm is referred to as a millimeter wave. An electromagnetic wave having a wavelength of 10 mm to 100 mm is referred to as a microwave. When an electromagnetic wave is transmitted to a person, the electromagnetic wave is reflected by an object present on a propagation path of the electromagnetic wave. By measuring the reflection intensity of the electromagnetic wave reflected at a certain distance, it is possible to determine whether the object present at the distance is a human body or a dangerous article such as a handgun or an explosive. Inspection accuracy is proportional to the number of transmit points of the electromagnetic wave (the number of antennas) per person.

[0087] An example of the antenna 72 is a microstrip antenna (also referred to as a patch antenna).

[0088] The signal processing unit 74 causes the antenna 72 to transmit an electromagnetic wave, causes the antenna 72 to receive a reflected wave, and processes a received signal from the antenna 72 to generate a signal representing belongings of the inspection target. The signal processing unit 74 may be formed integrally with the antenna 72, or may be formed separately from the antenna 72 and disposed at a position different from the antenna 72.

[0089] The storage 64 is a non-volatile storage device that stores programs executed by the CPU 62 and various pieces of data. The storage 64 includes an HDD, an SSD, or the like. The memory 66 is a nonvolatile memory that stores programs and data read from the storage 64 or various pieces of data generated during inspection. An example of the program is a program that causes the CPU 62 to execute the functions of the determination unit 24 and the update unit 28. The CPU 62 functions as the determination unit 24 and the update unit 28 by executing a program read from the storage 64 and stored in the memory 66. Note that the determination unit 24 and the update unit 28 may be formed by hardware.

[0090] The inspection device 10 may include a keyboard and a display device. The keyboard is used, for example, when a user sets a label. The display device may display an image of the inspection target to notify a person in charge of the inspection result.

[0091] FIG. 13 is a block diagram for explaining an example of the measurement unit 22 according to the arrangement. The antenna 72 includes one or more transmit antennas 72a and one or more receive antennas 72b. The transmit antenna 72a and the receive antenna 72b may not be separately provided. One antenna may transmit and electromagnetic wave and receive the reflected wave.

[0092] The signal processing unit 74 includes a synthesizer 82, a power amplifier 84, a low noise amplifier 86, a mixer 88, a low-pass filter (LPF) 90, an A/D converter (ADC) 92, and a fast Fourier transformation (FFT) circuit 94. The signal generated by the synthesizer 82 is amplified by the power amplifier 84 and then supplied to the transmit antenna 72a. An electromagnetic wave is transmitted from the transmit antenna 72a to the inspection range. The transmitted electromagnetic wave is reflected by all objects existing in the inspection range. The reflected wave is received by the receive antenna 72b. A received signal output from the receive antenna 72b is input to the first input terminal of the mixer 88 via the low noise amplifier 86. The output signal of the synthesizer 82 is input to the second input terminal of the mixer 88.

[0093] The mixer 88 combines the output signal of the synthesizer 82 and the received signal to generate an intermediate frequency (IF) signal. The intermediate frequency signal is input to the A/D converter 92 via the low-pass filter 90. The digital signal output from the A/D converter 92 is analyzed by the Fast Fourier transform (FFT) circuit 94, and the reflection intensity of the electromagnetic wave of the object is obtained.

[0094] The operation principle of the radar will be described. There are various combinations of transmit/receive antenna. For example, a reflected wave of an electromagnetic wave transmitted from one transmit antenna may be received by a plurality of receive antennas. Reflected waves of electromagnetic waves transmitted from a plurality of transmit antennas may be received by one receive antenna. Reflected waves of electromagnetic waves transmitted from a plurality of transmit antennas may be received by a plurality of receive antennas. Here, a method of obtaining the reflection intensity when a reflected wave of an electromagnetic wave transmitted from one transmit antenna is received by one receive antenna will be described.

[0095] The synthesizer 82 generates a frequency modulated continuous wave (FMCW) signal whose frequency linearly increases with the lapse of time. The FMCW signal is also referred to as a chirp signal. FIGS. 14A and 14B are diagrams for describing an example of a waveform of a chirp signal according to the arrangement. The chirp signal is as shown in FIG. 14A, where an amplitude "A" is expressed as a function of time t. The chirp signal is as shown in FIG. 14B, where a frequency f is expressed as a function of time t. As illustrated in FIG. 14B, the chirp signal is represented by a center frequency fc, a modulation bandwidth fb, and a signal time width Tb. The slope of the chirp signal is referred to as a frequency change rate (chirp rate) γ.

[0096] A transmission wave St(t) of the FMCW signal radiated from the transmit antenna 72a is expressed by Equation 1.

$$St(t) = \cos[2\pi(fc \cdot t + \gamma t2/2)] \quad \text{Equation 1}$$

[0097] The chirp rate γ is expressed by Equation 2.

$$\gamma = fb/Tb \quad \text{Equation 2}$$

[0098] The reflected wave from the object away from the transmit antenna 72a by the distance R is observed by the receive antenna 72b with a delay of $\Delta t = 2R/c$ from the transmission timing. "c" is the speed of light. When a reflection intensity of the object is "a", the received signal Sr(t) is expressed by Equation 3.

$$Sr(t) = a \cdot \cos[2\pi fc(t - \Delta t) + \pi\gamma (t - \Delta t)2] \quad \text{Equation 3}$$

[0099] FIGS. 15A to 15C are diagrams for explaining an example of a received signal in the signal processing unit 74 in a case where there is a plurality of objects, for example, three objects according to the arrangement. FIG. 15A illustrates a relationship between a transmitted signal/received signal and time. As illustrated in FIG. 15A, the frequency of the transmitted signal linearly changes with time. The received signal is delayed by Δt with respect to the transmitted signal. In a case where there is a plurality of objects, a reflected wave from the closest object is received earliest as indicated by a broken line. A reflected wave from the farthest object is received last as indicated by an alternate long and short dash line.

[0100] As illustrated in FIG. 13, the received signal is multiplied by the transmitted signal in the mixer 88 and input to the low-pass filter 90. The output signal of the low-pass filter 90 is referred to as an IF signal z(t) and is expressed by Equation 4.

$$z(t) = a \cdot \cos(2\pi\Delta t\gamma t) \quad \text{Equation 4}$$

[0101] FIG. 15B illustrates a relationship between the frequency of the IF signal and time. Under an ideal environment without noise or the like, the frequency is constant for each reflected wave. Here, the frequency of the reflected wave from the closest object is the lowest as indicated by a broken line. The frequency of the reflected wave from the farthest object is the highest as indicated by an alternate long and short dash line.

[0102] The reflection intensity in the frequency domain can be calculated by performing FFT on the IF signal z(t) in the time domain illustrated in Equation 4 in the FFT circuit 94. Therefore, the amplitude at each point in the frequency domain that is the result of the FFT of the IF signal corresponds to the reflection intensity for each distance from the radar. The frequency and the distance from the radar have the relationship of Equation 5.

$$fif = \Delta t\gamma = 2R\gamma/c \quad \text{Equation 5}$$

[0103] FIG. 15C illustrates a relationship between the reflection intensity and the frequency obtained by performing the FFT on the IF signal in the time domain. In this manner, by obtaining the amplitude of the frequency domain signal of the IF signal, the reflection intensity for each distance from the radar can be obtained.

[0104] When the inspection device 10 is installed, the distance between the inspection device 10 and the inspection target 18 is determined. For example, assuming that the distance between the inspection device 10 and the inspection target 18 is two meters, the measurement unit 22 obtains the frequency fif of the IF signal corresponding to the point at the distance R (= two meters) from Equation 5. The measurement unit 22 can extract the reflection intensity of the frequency fif as the reflection intensity of the object from among the reflection intensities of a large number of received signals as illustrated in FIG. 15C.

[0105] The above-described processing is performed for each transmit point while changing (scanning) the transmit point of the electromagnetic wave along the scanning direction.

[0106] FIGS. 16A to 16C are diagrams for explaining an example of the reflection intensity distribution according to the arrangement. As illustrated in FIGS. 16A to 16C, the distribution of the reflection intensity of the electromagnetic wave on the scanning line varies depending on the substance that reflects the electromagnetic wave.

[0107] FIG. 16A illustrates a reflection intensity distribution of an electromagnetic wave in a case where the inspection

target (for example, human) possesses nothing. Since the electromagnetic wave is reflected by the skin of the inspection target, the reflection intensity of the electromagnetic wave does not change regardless of the position of the transmit point. The distribution of the reflection intensity is a flat distribution. The reflection intensity distribution in FIG. 16A is a reference reflection intensity distribution corresponding to a reference inspection result.

[0108] FIG. 16B illustrates the reflection intensity distribution of the electromagnetic wave in a case where the inspection target has a handgun (metal) at the center in the scanning direction. Since metal has a higher reflection intensity than skin, the reflection intensity of the electromagnetic wave at the transmit point corresponding to the position of the handgun is higher than the reflection intensity of the electromagnetic wave at other points. Since the horizontal axis indicates the reflection intensity (the right indicates a high reflection intensity), the reflection intensity of the electromagnetic wave has a distribution protruding to the right.

[0109] FIG. 16C illustrates the reflection intensity distribution of the electromagnetic wave in a case where the inspection target has the explosive at the center in the scanning direction. Since the explosive absorbs the electromagnetic wave better than the skin, the reflection intensity at the transmit point corresponding to the position of the explosive is lower than the reflection intensity at other points. The reflection intensity of the electromagnetic wave has a distribution protruding to the left. The distribution can be identified by a difference between the reflection intensity values at least at two points.

[0110] Since the measurement unit 22 is only required to be able to estimate a region where there is a possibility that a predetermined object exists, a high resolution for a difference (for example, 1 cm) between the clothing and the human body is not required as the resolution in the distance direction. A resolution of about several cm is sufficient. The measurement unit 22 can use an inexpensive in-vehicle millimeter wave radar that is currently in circulation.

[0111] When the reflection intensity of the inspection target is acquired at several points (at least two points) on the scanning line in this manner, the determination unit 24 determines the belongings using the machine learning model 26 based on the reflection intensity.

[0112] The determination unit 24 may determine the belongings without using the machine learning model 26. The determination unit 24 may compare the shape of the reflection intensity distribution output from measurement unit 22 with the distribution shape of the reference reflection intensity. The reference reflection intensity may include a reflection intensity distribution of an inspection target having no belongings, a reflection intensity distribution of an inspection target having a metal object such as a handgun, or a reflection intensity distribution of an inspection target having a powder target such as an explosive.

[0113] According to the inspection system of the arrangement, the plurality of inspection devices sequentially perform the inspection while gradually increasing the reliability of the detection. When a certain inspection device has achieved the detection target, the detection result is fed back to another inspection device. In a case where the machine learning model is used for the inspection, another inspection device updates the machine learning model based on the detection result. As a result, the reliability of the inspection result by another inspection device is improved.

[0114] While certain arrangements have been described, these arrangements have been presented by way of example only, and are not intended to limit the scope of the claims. Indeed, the system and method described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the system and method described herein may be made.

[0115] The arrangements as described above include clauses below.

Clause 1

[0116] An inspection system characterized by comprising:

a first measurement unit (22a) configured to measure a target;
a first determination unit (24a) configured to make a first determination on whether the target includes a predetermined object using a first machine learning model (26a) based on a measurement result by the first measurement unit (22a);
a second measurement unit (22b) configured to measure the target;
a second determination unit (24b) configured to make a second determination on whether the target includes the predetermined object based on a measurement result by the second measurement unit (22b); and
a processing unit (12) configured to generate first update data of the first machine learning model (26a) based on a result of the second determination and transmit the first update data to the first determination unit (24a).

Clause 2

[0117] The inspection system of Clause 1, characterized in that
the first determination unit (24a) is configured to update the first machine learning model (26a) based on the first update data.

Clause 3

[0118] The inspection system of Clause 2, characterized in that
the first determination unit (24a) is configured to make the first determination again after updating the first machine learning model (26a).

Clause 4

[0119] The inspection system of Clause 1, characterized in that
the second determination unit (24b) is configured to make the second determination using a second machine learning model based on the measurement result by the second measurement unit (22b).

Clause 5

[0120] The inspection system of one of Clause 1 to Clause 4, characterized in that

the first measurement unit (22a) is configured to obtain a first feature amount of the target;
the second measurement unit (22b) is configured to obtain a second feature amount of the target; and
the second feature amount is different from the first feature amount.

Clause 6

[0121] The inspection system of one of Clause 1 to Clause 4, characterized in that

the first measurement unit (22a) is configured to obtain a feature amount of the target at a first level of detail;
the second measurement unit (22b) is configured to obtain the feature amount at a second level of detail; and
the second level of detail is higher than the first level of detail.

Clause 7

[0122] The inspection system of one of Clause 1 to Clause 4, characterized in that
reliability of the second determination is higher than reliability of the first determination.

Clause 8

[0123] The inspection system of one of Clause 1 to Clause 4, characterized in that
the second measurement unit (22b) is configured to measure the target after the first measurement unit (22a) measures the target.

Clause 9

[0124] The inspection system of one of Clause 1 to Clause 4, characterized in that
each of the first measurement unit (22a) and the second measurement unit (22b) comprises a radar, a metal detector, a liquid detector, an X-ray diagnosis device, or a camera.

Clause 10

[0125] The inspection system of one of Clause 1 to Clause 4, characterized in that
the second measurement unit (22b) comprises a metal detector or a camera.

Clause 11

[0126] The inspection system of Clause 1, further comprising:

a third measurement unit (22c) configured to measure the target; and
a third determination unit (24c) configured to make a third determination on whether the target includes the predetermined object based on a measurement result by the third measurement unit (22c), and characterized in that
the third measurement unit (22c) is configured to measure the target after the first measurement unit (22a) measures

the target; and
the second measurement unit (22b) is configured to measure the target after the third measurement unit (22c) measures the target.

Clause 12

[0127] The inspection system of Clause 11, characterized in that

the third determination unit (24c) is configured to make the third determination using a third machine learning model (26c) based on the measurement result by the third measurement unit (22c);
the processing unit (12) is configured to generate second update data of the third machine learning model (26c) based on a result of the second determination and transmit the second update data to the third determination unit (24c); and
the third determination unit (24c) is configured to update the third machine learning model (26c) based on the second update data.

Clause 13

[0128] The inspection system of Clause 12, characterized in that
the third determination unit (24c) is configured to make the third determination again after updating the third machine learning model (26c).

Clause 14

[0129] The inspection system of one of Clause 11 to Clause 13, characterized in that

the first measurement unit (22a) is configured to obtain a first feature amount of the target;
the second measurement unit (22b) is configured to obtain a second feature amount of the target;
the third measurement unit (22c) is configured to measure a third feature amount of the target;
the second feature amount is different from the first feature amount; and
the third feature amount is different from the second feature amount.

Clause 15

[0130] The inspection system of one of Clause 11 to Clause 13, characterized in that

the first measurement unit (22a) is configured to measure a feature amount of the target at a first level of detail;
the third measurement unit (22c) is configured to measure the feature amount at a third level of detail;
the second measurement unit (22b) is configured to measure the feature amount at a second level of detail; and
the second level of detail is higher than the first level of detail and the third level of detail.

Clause 16

[0131] The inspection system of one of Clause 11 to Clause 13, characterized in that
reliability of the second determination is higher than reliability of the first determination and reliability of the third determination.

Clause 17

[0132] An inspection method comprising:

making a first determination on whether a target includes a predetermined object using a machine learning model (26a) based on a measurement result by a first measurement unit (22a) configured to measure a target;
making a second determination on whether the target includes the predetermined object based on a measurement result by a second measurement unit (22b) configured to measure the target;
generating update data of the machine learning model (26a) based on a result of the second determination; and
transmitting the update data to the machine learning model (26a).

Claims

1. An inspection system **characterized by** comprising:

   a first measurement unit (22a) configured to measure a target;
   a first determination unit (24a) configured to make a first determination on whether the target includes a predetermined object using a first machine learning model (26a) based on a measurement result by the first measurement unit (22a);
   a second measurement unit (22b) configured to measure the target;
   a second determination unit (24b) configured to make a second determination on whether the target includes the predetermined object based on a measurement result by the second measurement unit (22b); and
   a processing unit (12) configured to generate first update data of the first machine learning model (26a) based on a result of the second determination and transmit the first update data to the first determination unit (24a).

2. The inspection system of claim 1, **characterized in that**
   the first determination unit (24a) is configured to update the first machine learning model (26a) based on the first update data.

3. The inspection system of claim 2, **characterized in that**
   the first determination unit (24a) is configured to make the first determination again after updating the first machine learning model (26a).

4. The inspection system of claim 1, **characterized in that**
   the second determination unit (24b) is configured to make the second determination using a second machine learning model based on the measurement result by the second measurement unit (22b).

5. The inspection system of one of claim 1 to claim 4, **characterized in that**

   the first measurement unit (22a) is configured to obtain a first feature amount of the target,
   the second measurement unit (22b) is configured to obtain a second feature amount of the target, and
   the second feature amount is different from the first feature amount.

6. The inspection system of one of claim 1 to claim 4, **characterized in that**

   the first measurement unit (22a) is configured to obtain a feature amount of the target at a first level of detail,
   the second measurement unit (22b) is configured to obtain the feature amount at a second level of detail, and
   the second level of detail is higher than the first level of detail.

7. The inspection system of one of claim 1 to claim 4, **characterized in that**
   reliability of the second determination is higher than reliability of the first determination.

8. The inspection system of one of claim 1 to claim 4, **characterized in that**
   the second measurement unit (22b) is configured to measure the target after the first measurement unit (22a) measures the target.

9. The inspection system of one of claim 1 to claim 4, **characterized in that**
   each of the first measurement unit (22a) and the second measurement unit (22b) comprises a radar, a metal detector, a liquid detector, an X-ray diagnosis device, or a camera.

10. The inspection system of one of claim 1 to claim 4, **characterized in that**
    the second measurement unit (22b) comprises a metal detector or a camera.

11. The inspection system of claim 1, further comprising:

    a third measurement unit (22c) configured to measure the target; and
    a third determination unit (24c) configured to make a third determination on whether the target includes the predetermined object based on a measurement result by the third measurement unit (22c), and **characterized in that**

the third measurement unit (22c) is configured to measure the target after the first measurement unit (22a) measures the target, and
the second measurement unit (22b) is configured to measure the target after the third measurement unit (22c) measures the target.

12. The inspection system of claim 11, **characterized in that**

the third determination unit (24c) is configured to make the third determination using a third machine learning model (26c) based on the measurement result by the third measurement unit (22c),
the processing unit (12) is configured to generate second update data of the third machine learning model (26c) based on a result of the second determination and transmit the second update data to the third determination unit (24c), and
the third determination unit (24c) is configured to update the third machine learning model (26c) based on the second update data.

13. The inspection system of claim 12, **characterized in that**
the third determination unit (24c) is configured to make the third determination again after updating the third machine learning model (26c).

14. The inspection system of one of claim 11 to claim 13, **characterized in that**

the first measurement unit (22a) is configured to obtain a first feature amount of the target,
the second measurement unit (22b) is configured to obtain a second feature amount of the target,
the third measurement unit (22c) is configured to measure a third feature amount of the target,
the second feature amount is different from the first feature amount, and
the third feature amount is different from the second feature amount.

15. An inspection method comprising:

making a first determination on whether a target includes a predetermined object using a machine learning model (26a) based on a measurement result by a first measurement unit (22a) configured to measure a target;
making a second determination on whether the target includes the predetermined object based on a measurement result by a second measurement unit (22b) configured to measure the target;
generating update data of the machine learning model (26a) based on a result of the second determination; and
transmitting the update data to the machine learning model (26a).

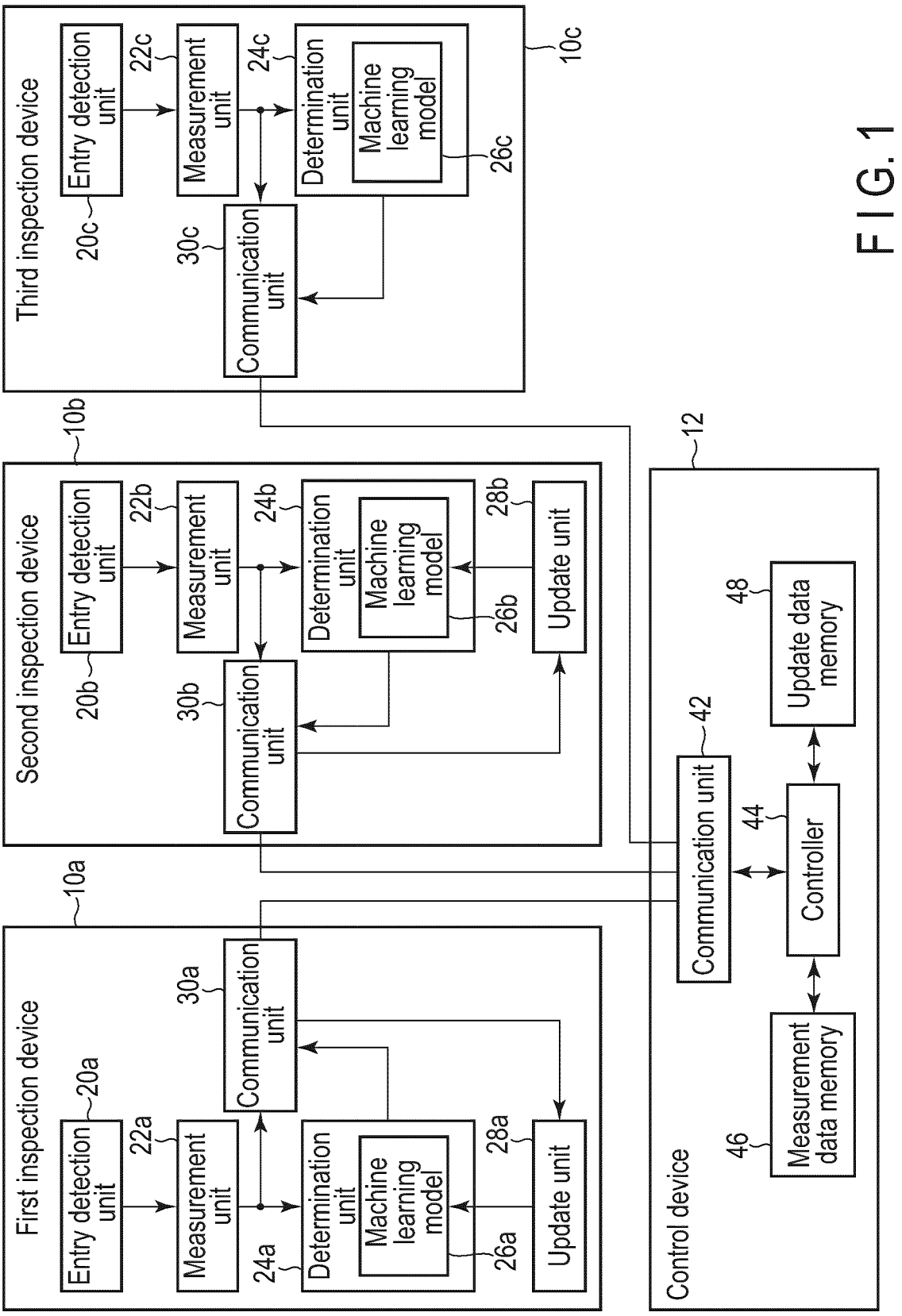

Third inspection device
10c
Entry detection unit
20c
22c
Measurement unit
24c
Determination unit
Machine learning model
26c
30c
Communication unit
Second inspection device
10b
Entry detection unit
20b
22b
Measurement unit
24b
Determination unit
Machine learning model
26b
28b
Update unit
30b
Communication unit
First inspection device
10a
Entry detection unit
20a
22a
Measurement unit
24a
Determination unit
Machine learning model
26a
28a
Update unit
30a
Communication unit
12
Control device
Communication unit
42
44
Controller
46
Measurement data memory
48
Update data memory

FIG. 1

Machine learning model 26a

First measurement data	First labels
M1	L1
M2	L2
M3	L3
...	...

FIG. 2

Measurement data memory 46

Inspection target ID	First measurement data	Second measurement data	Third measurement data	Third label
00000000	M10	M20	M30	L30a,L30b,L30c
00000001	M11	M21	M31	L31a,L31b,L31c
00000002	M12	M22	M32	L32a,L32b,L32c
...	...	...	...	...

FIG. 3

Update data memory 48

First update data		Second update data	
First measurement data	First teacher label	Second measurement data	Second teacher label
M10	L30a	M20	L30b,L30c
M11	L31a	M21	L31b,L31c
M12	L32a	M22	L32b,L32c
...	...	...	...

FIG. 4

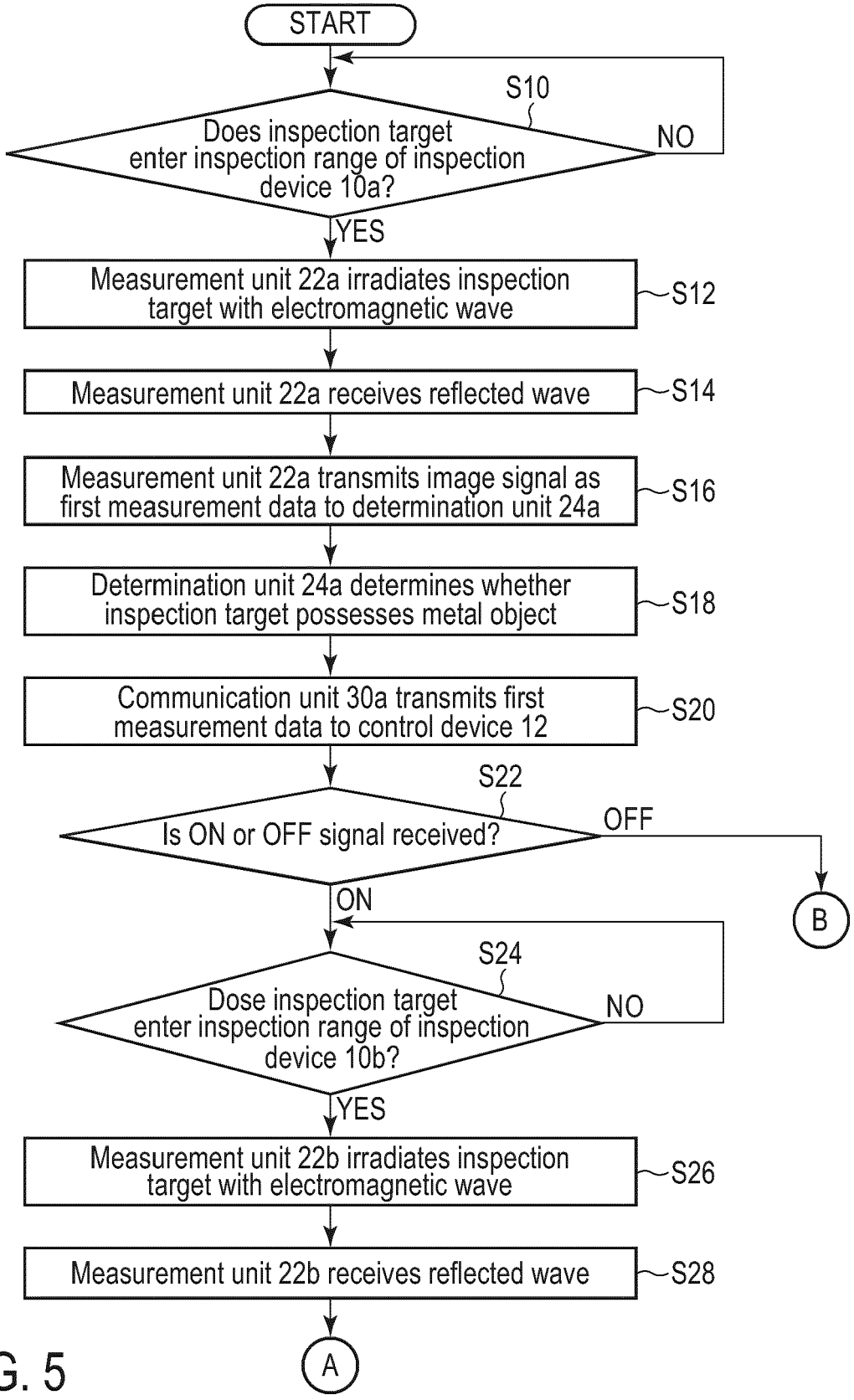

START
S10
Does inspection target enter inspection range of inspection device 10a?
NO
YES
Measurement unit 22a irradiates inspection target with electromagnetic wave
S12
Measurement unit 22a receives reflected wave
S14
Measurement unit 22a transmits image signal as first measurement data to determination unit 24a
S16
Determination unit 24a determines whether inspection target possesses metal object
S18
Communication unit 30a transmits first measurement data to control device 12
S20
S22
Is ON or OFF signal received?
OFF
B
ON
S24
Dose inspection target enter inspection range of inspection device 10b?
NO
YES
Measurement unit 22b irradiates inspection target with electromagnetic wave
S26
Measurement unit 22b receives reflected wave
S28
A

FIG. 5

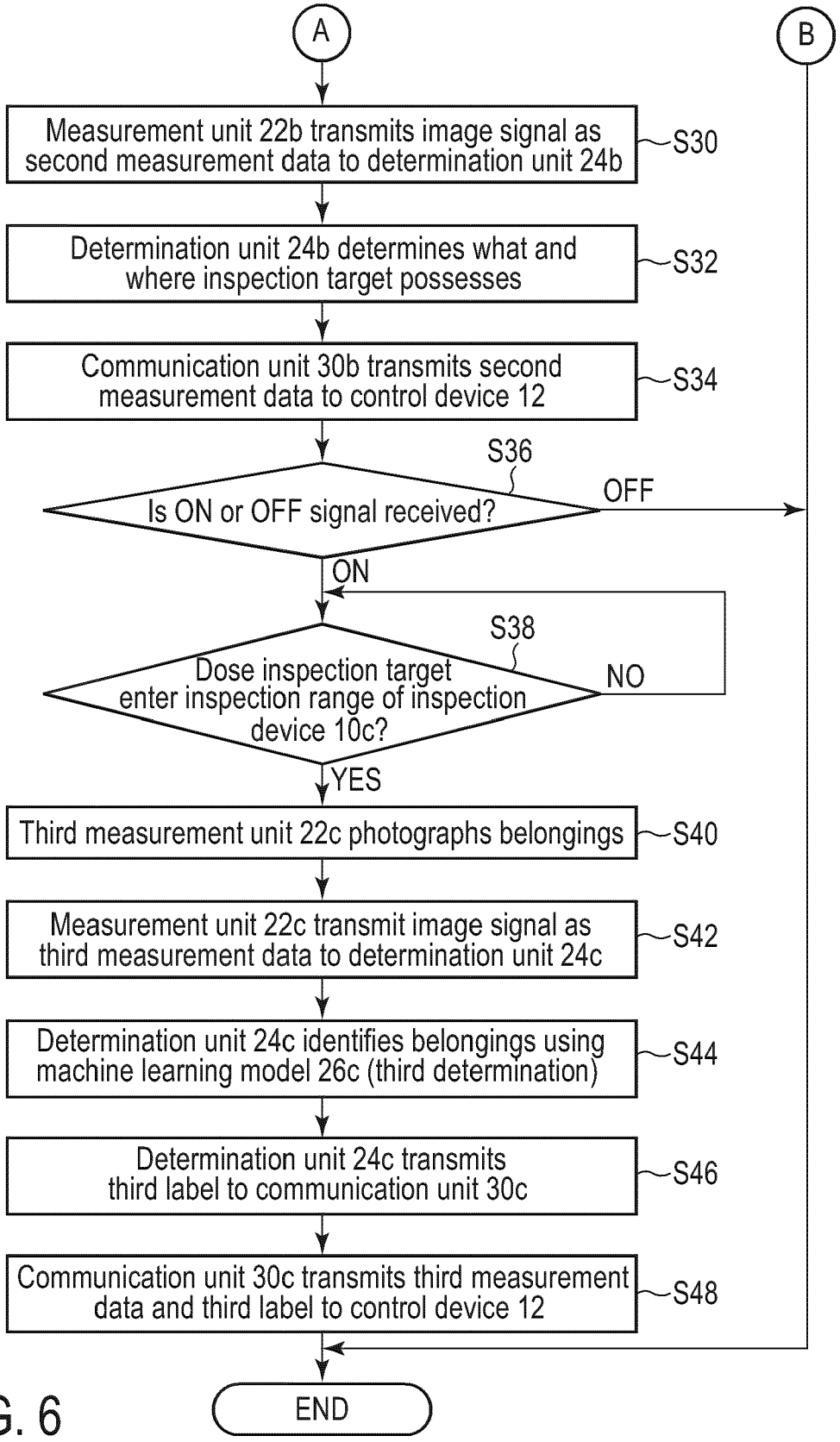

A
B
Measurement unit 22b transmits image signal as second measurement data to determination unit 24b
S30
Determination unit 24b determines what and where inspection target possesses
S32
Communication unit 30b transmits second measurement data to control device 12
S34
S36
Is ON or OFF signal received?
OFF
ON
S38
Dose inspection target enter inspection range of inspection device 10c?
NO
YES
Third measurement unit 22c photographs belongings
S40
Measurement unit 22c transmit image signal as third measurement data to determination unit 24c
S42
Determination unit 24c identifies belongings using machine learning model 26c (third determination)
S44
Determination unit 24c transmits third label to communication unit 30c
S46
Communication unit 30c transmits third measurement data and third label to control device 12
S48
END

FIG. 6

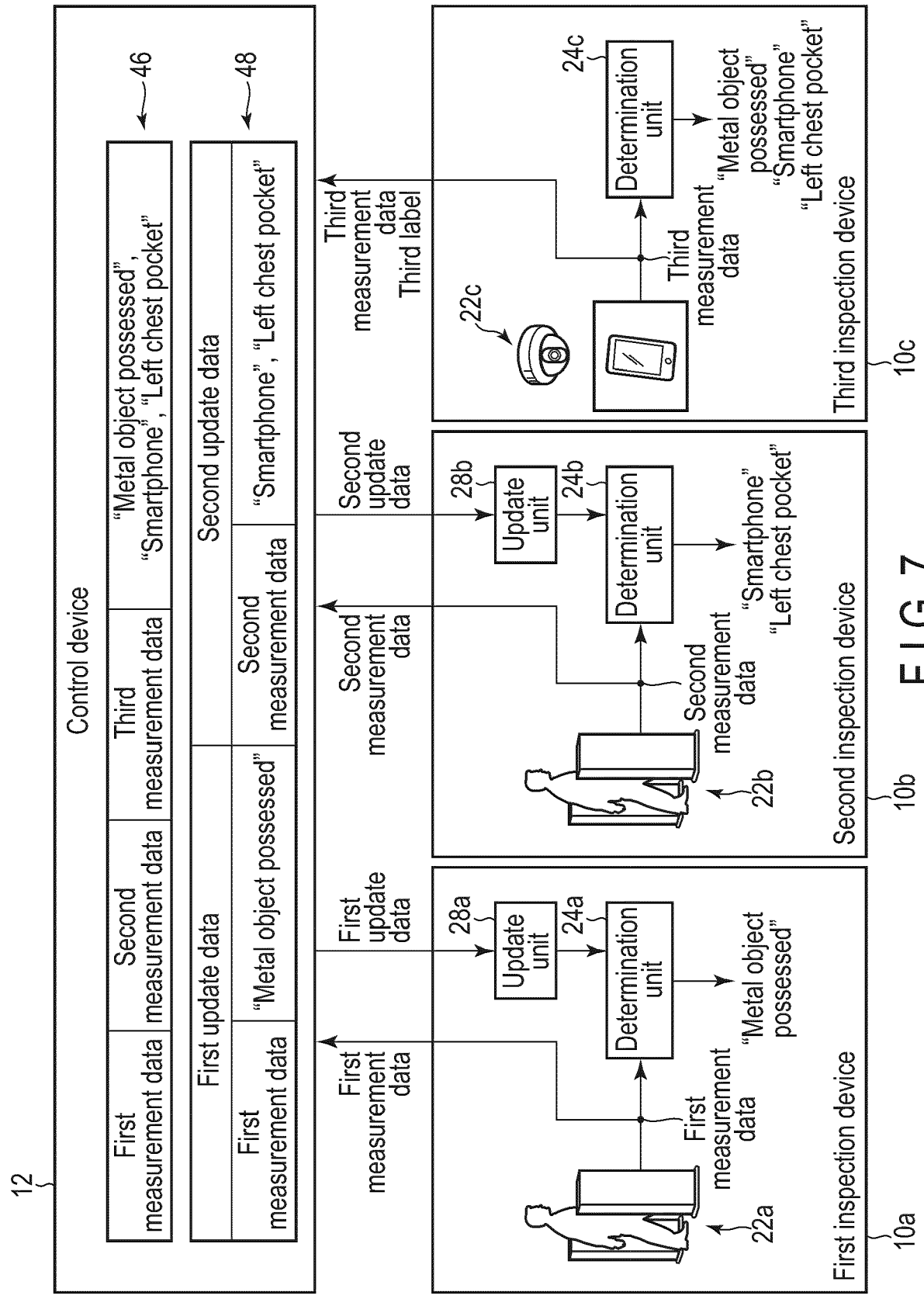

12
Control device
First measurement data
Second measurement data
Third measurement data
"Metal object possessed", "Smartphone", "Left chest pocket"
46
First update data
First measurement data
"Metal object possessed"
Second update data
Second measurement data
"Smartphone", "Left chest pocket"
48
First measurement data
First update data
Second measurement data
Second update data
Third measurement data
Third label
First inspection device
10a
22a
First measurement data
28a
Update unit
24a
Determination unit
"Metal object possessed"
Second inspection device
10b
22b
Second measurement data
28b
Update unit
24b
Determination unit
"Smartphone"
"Left chest pocket"
Third inspection device
10c
22c
Third measurement data
24c
Determination unit
"Metal object possessed"
"Smartphone"
"Left chest pocket"

FIG. 7

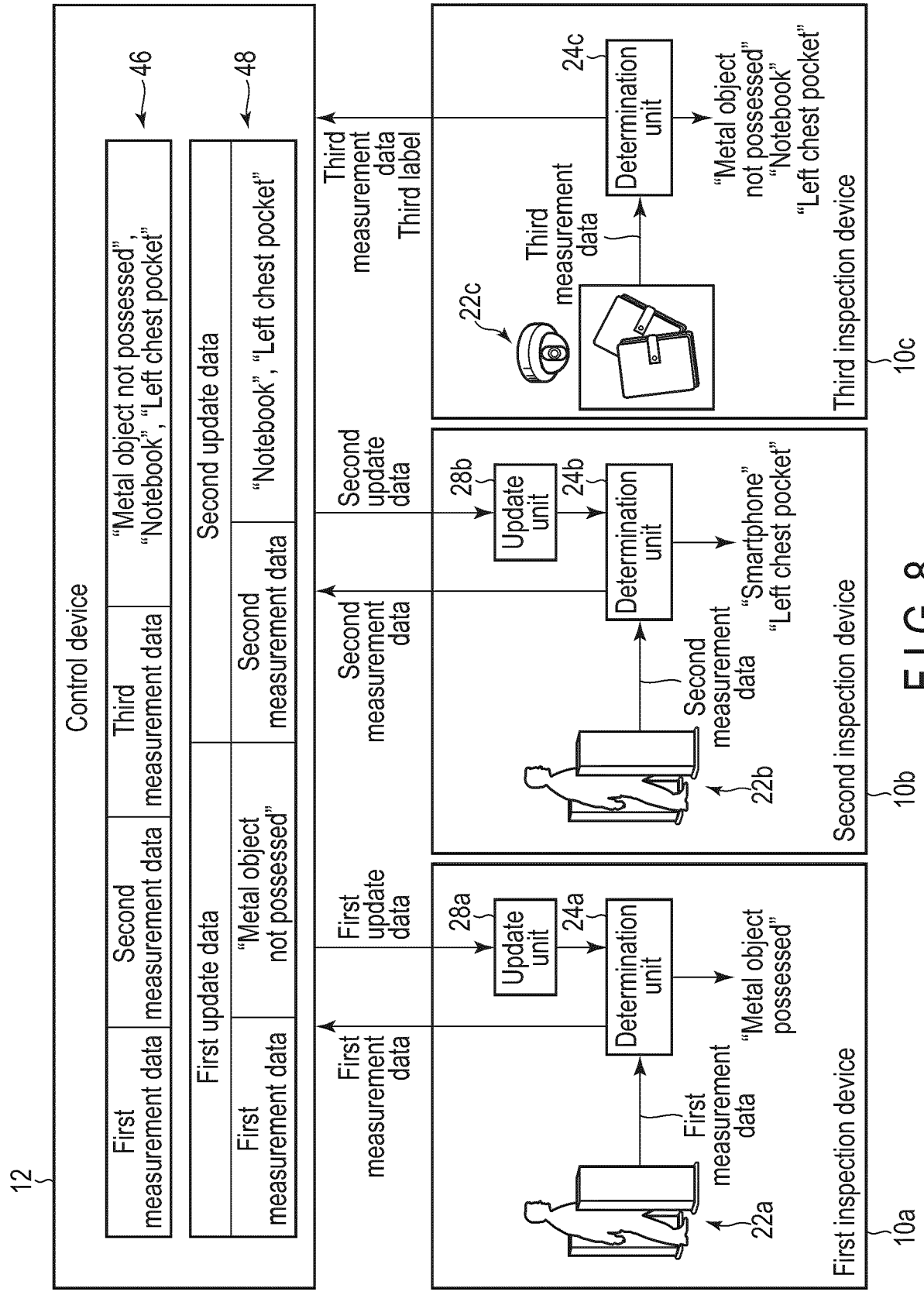

12
Control device
First measurement data
Second measurement data
Third measurement data
"Metal object not possessed", "Notebook", "Left chest pocket"
46
First update data
First measurement data
"Metal object not possessed"
Second update data
Second measurement data
"Notebook", "Left chest pocket"
48
First measurement data
First update data
Second measurement data
Second update data
Third measurement data
Third label
First inspection device
10a
22a
First measurement data
Determination unit
24a
Update unit
28a
"Metal object possessed"
Second inspection device
10b
22b
Second measurement data
Determination unit
24b
Update unit
28b
"Smartphone"
"Left chest pocket"
Third inspection device
10c
22c
Third measurement data
Determination unit
24c
"Metal object not possessed"
"Notebook"
"Left chest pocket"

FIG. 8

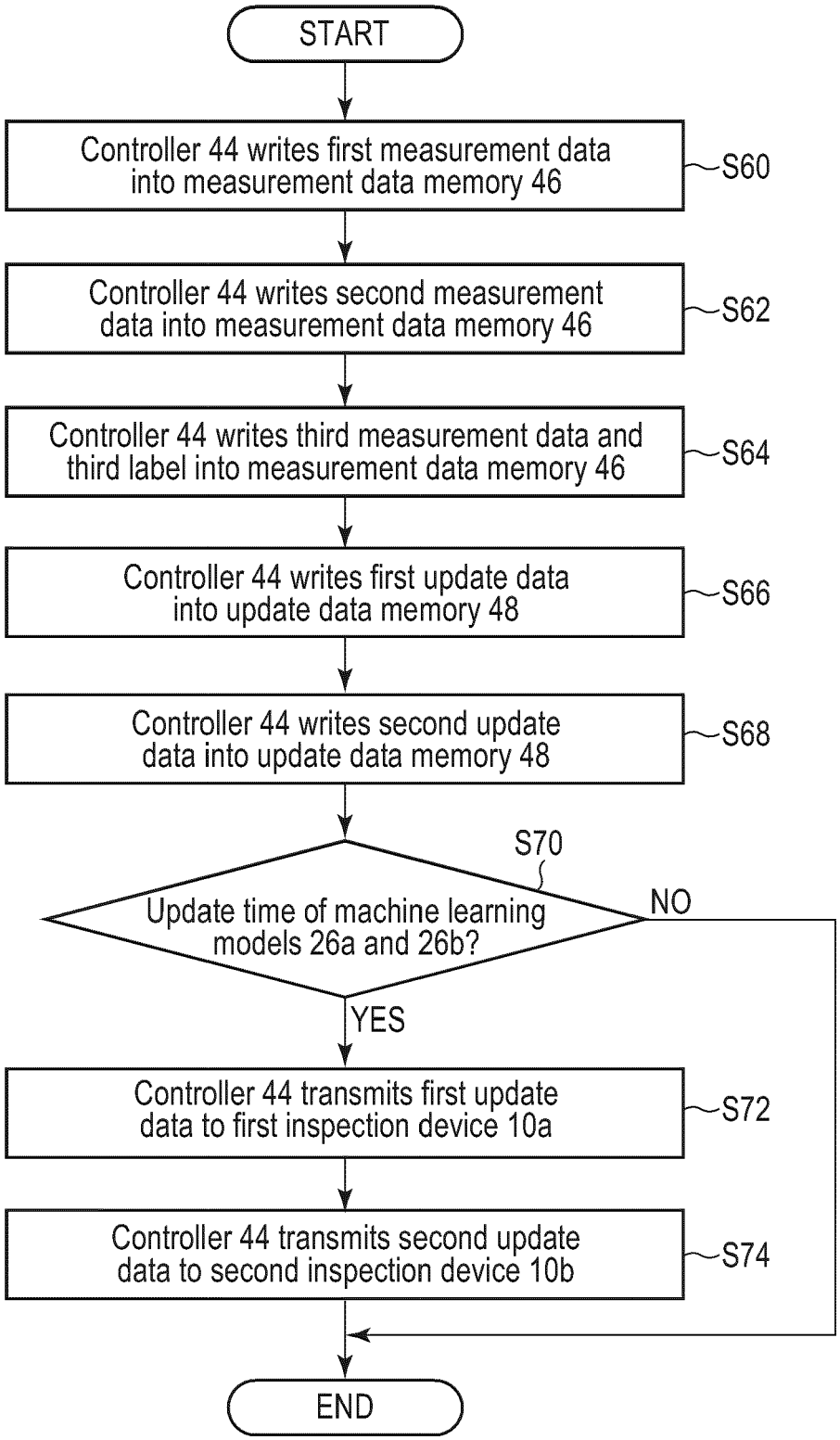

START
Controller 44 writes first measurement data into measurement data memory 46
S60
Controller 44 writes second measurement data into measurement data memory 46
S62
Controller 44 writes third measurement data and third label into measurement data memory 46
S64
Controller 44 writes first update data into update data memory 48
S66
Controller 44 writes second update data into update data memory 48
S68
S70
Update time of machine learning models 26a and 26b?
NO
YES
Controller 44 transmits first update data to first inspection device 10a
S72
Controller 44 transmits second update data to second inspection device 10b
S74
END

FIG. 9

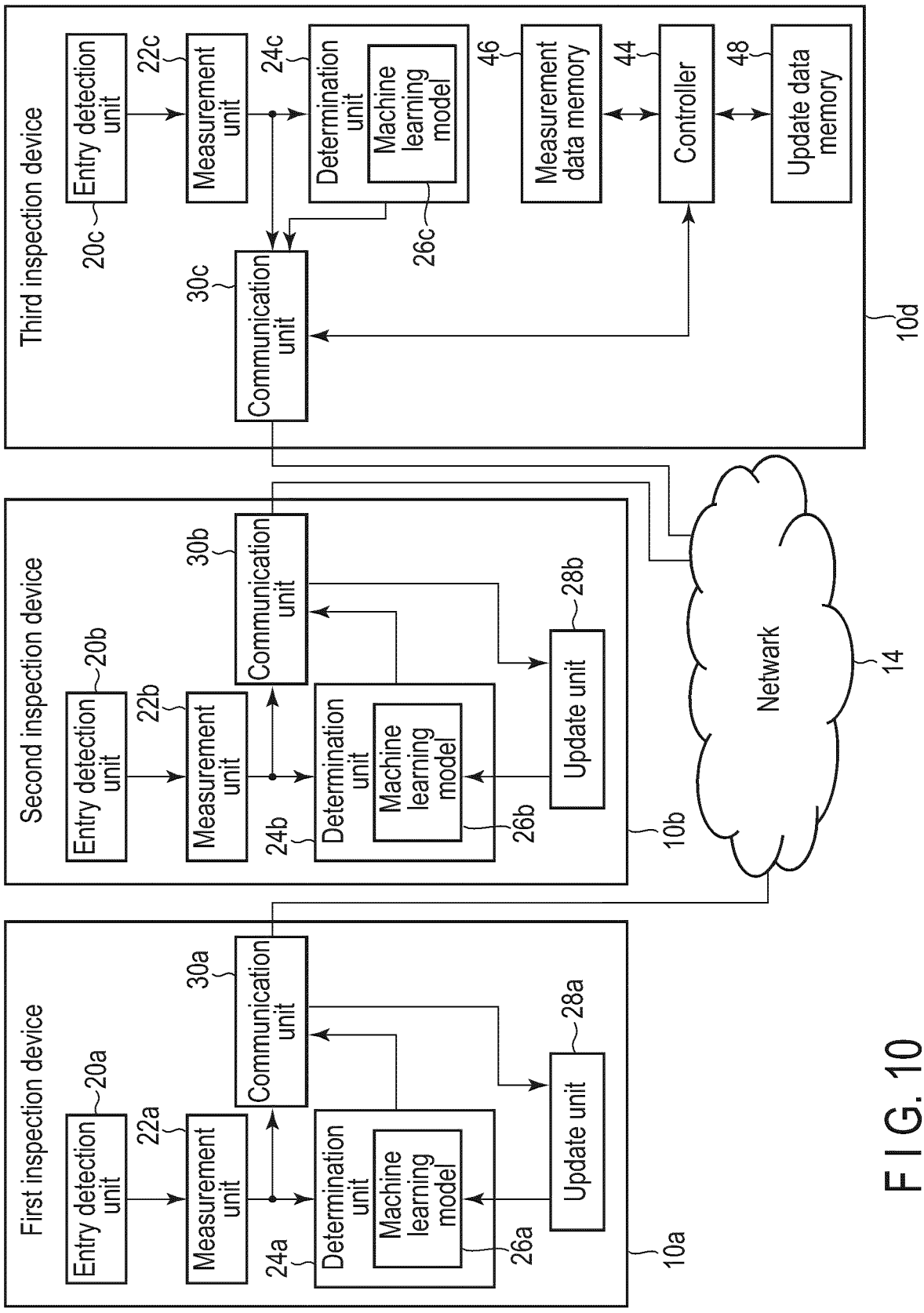

First inspection device
Entry detection unit
20a
Measurement unit
22a
Determination unit
Machine learning model
24a
26a
Update unit
28a
Communication unit
30a
10a
Second inspection device
Entry detection unit
20b
Measurement unit
22b
Determination unit
Machine learning model
24b
26b
Update unit
28b
Communication unit
30b
10b
Network
14
Third inspection device
Entry detection unit
20c
Measurement unit
22c
Determination unit
Machine learning model
24c
26c
Communication unit
30c
Measurement data memory
46
Controller
44
Update data memory
48
10d

FIG. 10

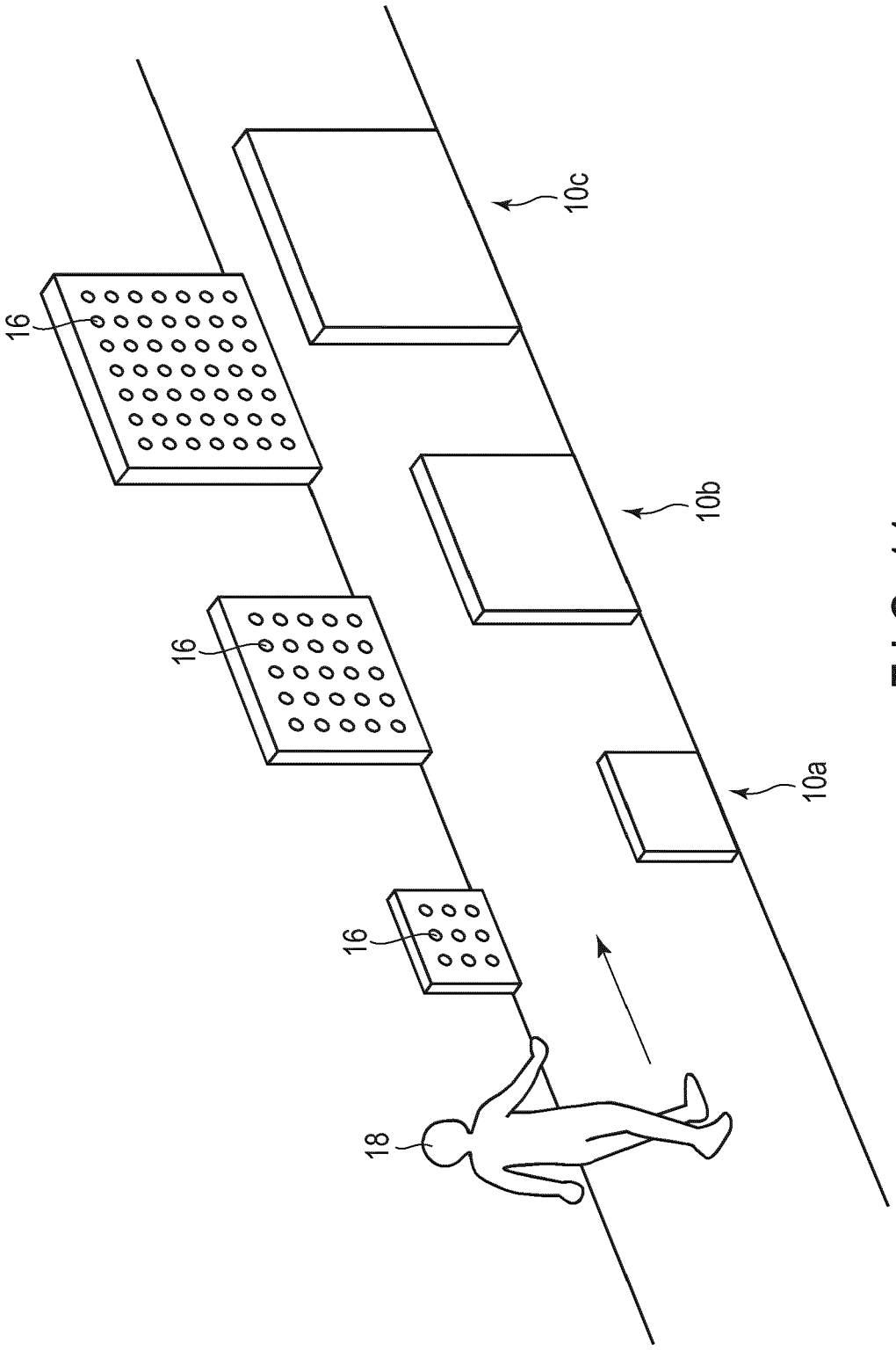


FIG. 11

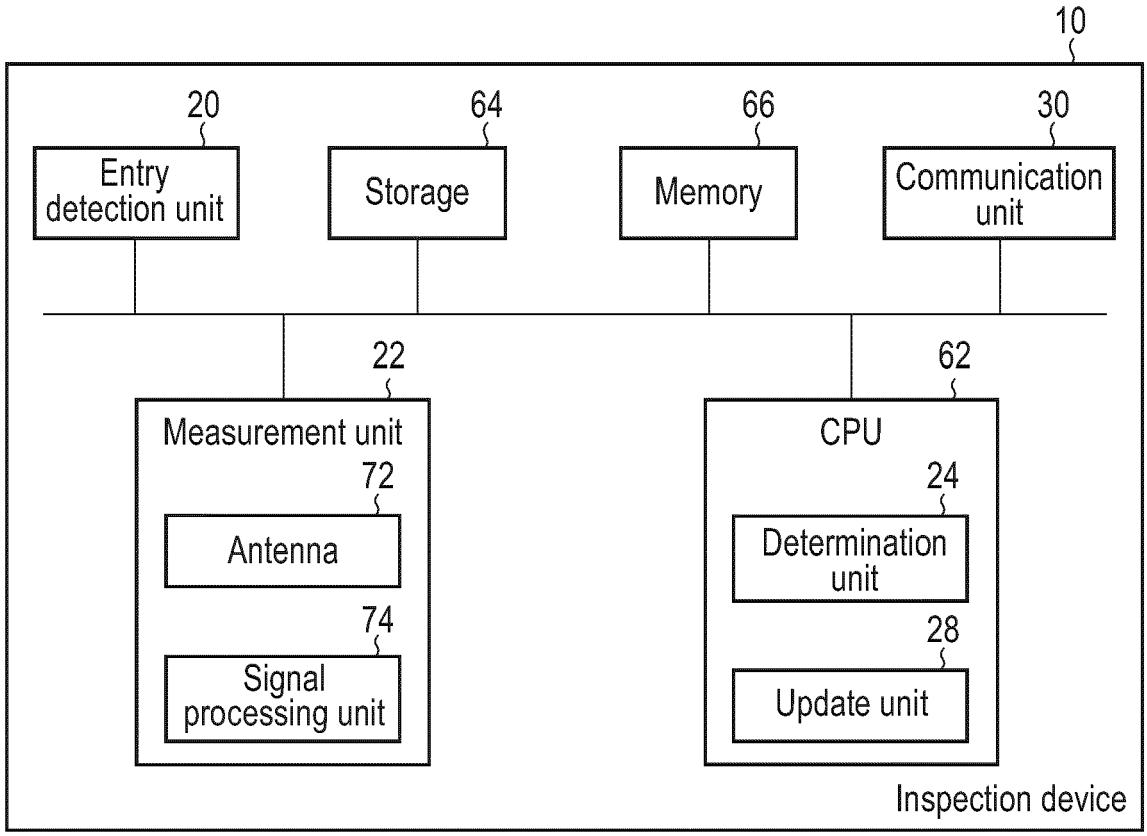

10
20
Entry detection unit
64
Storage
66
Memory
30
Communication unit
22
Measurement unit
72
Antenna
74
Signal processing unit
62
CPU
24
Determination unit
28
Update unit
Inspection device

FIG. 12

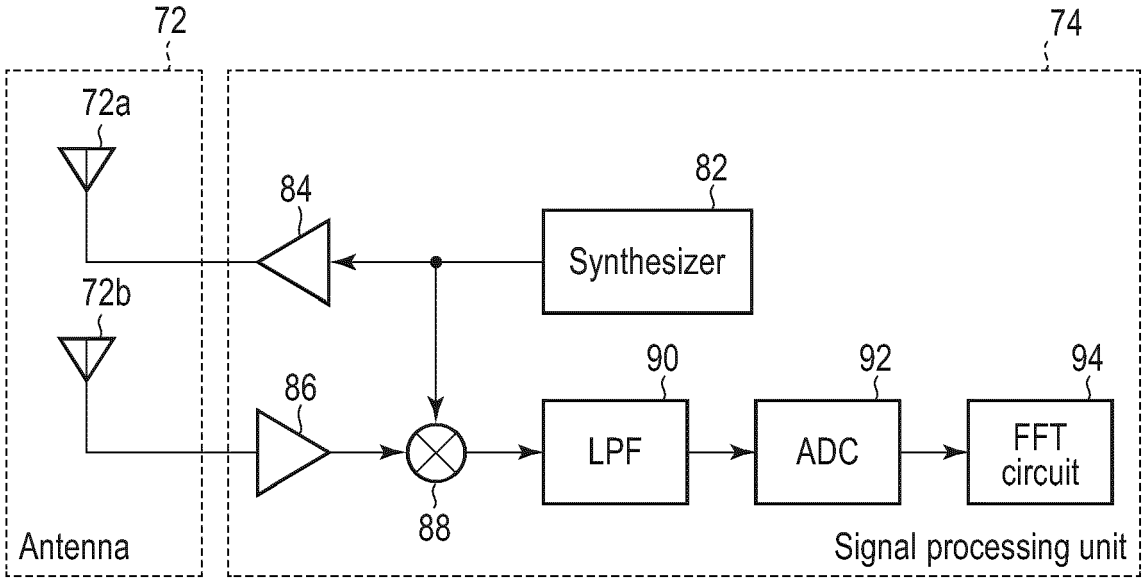

72
74
72a
72b
84
82
Synthesizer
86
90
92
94
LPF
ADC
FFT circuit
88
Antenna
Signal processing unit

FIG. 13

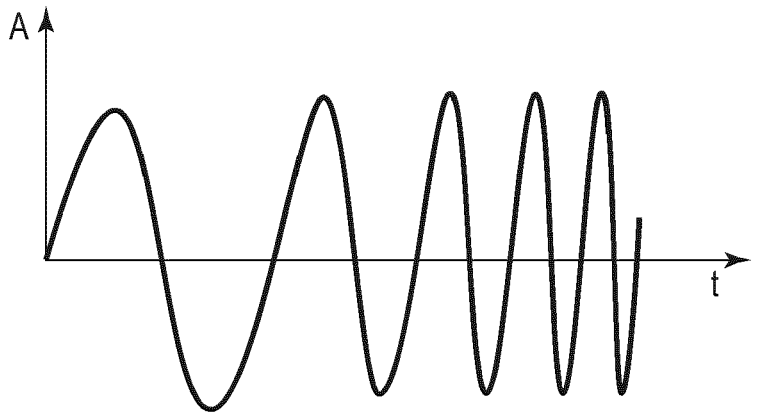


FIG. 14A

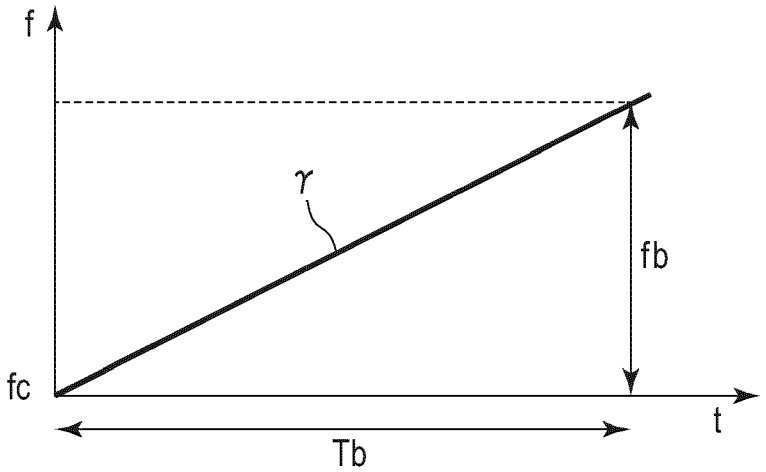


FIG. 14B

FIG. 15A

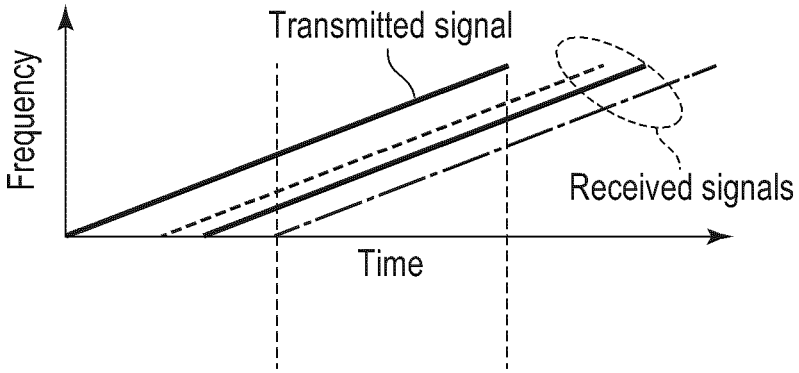
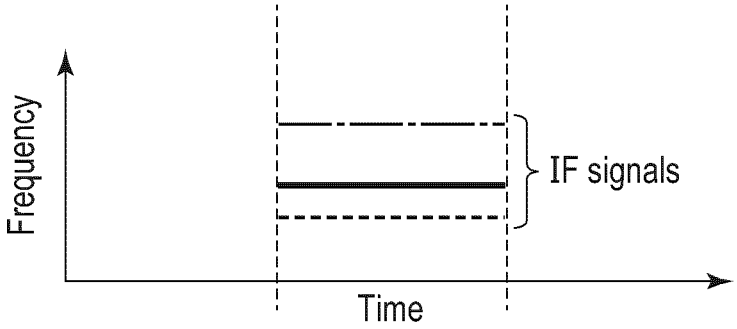


FIG. 15B



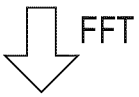


FIG. 15C

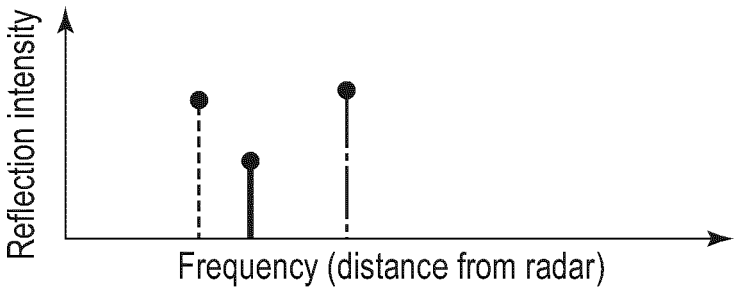


FIG. 16A

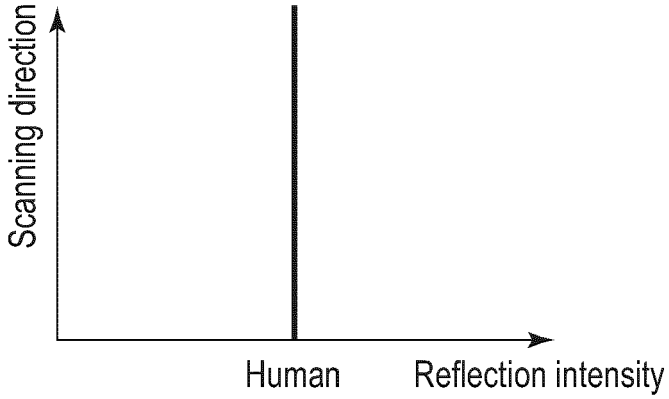


FIG. 16B

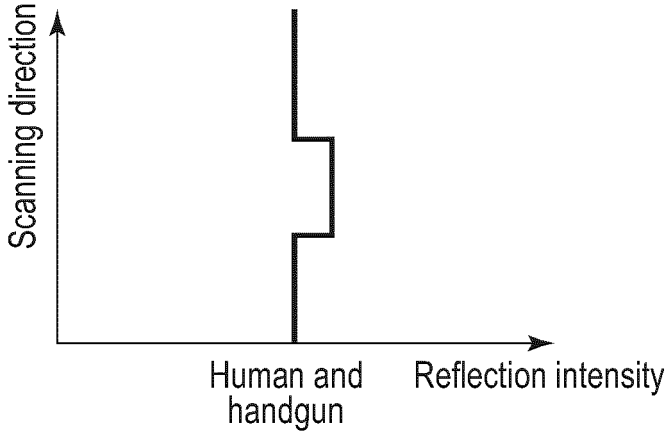
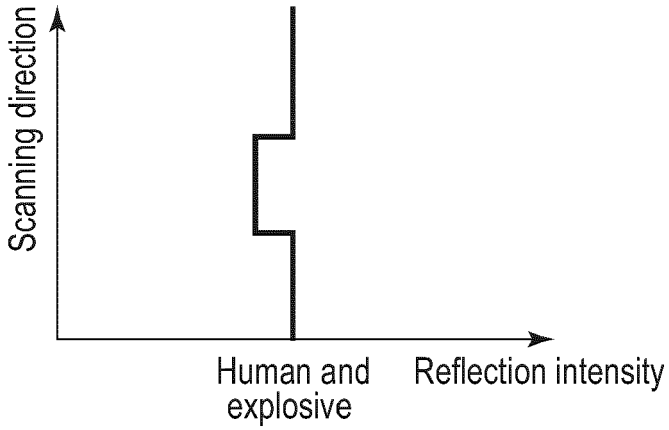


FIG. 16C



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EUROPEAN SEARCH REPORT

Application Number
EP 23 21 2958

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	MARVIN KLINGNER ET AL: "X^3KD: Knowledge Distillation Across Modalities, Tasks and Stages for Multi-Camera 3D Object Detection", ARXIV.ORG, CORNELL UNIVERSITY LIBRARY, 201 OLIN LIBRARY CORNELL UNIVERSITY ITHACA, NY 14853, 3 March 2023 (2023-03-03), XP091453088, * abstract * * Sections 1, 3, 4, 5 * * figures 1, 2 * -----	1-15	INV. G06N3/045 G01S13/00 G01S17/00 G06N3/096 G06V10/00
X	CHEN HONGYUAN ET AL: "Super-resolution guided knowledge distillation for low-resolution image classification", PATTERN RECOGNITION LETTERS, ELSEVIER, AMSTERDAM, NL, vol. 155, 13 February 2022 (2022-02-13), pages 62-68, XP086994203, ISSN: 0167-8655, DOI: 10.1016/J.PATREC.2022.02.006 [retrieved on 2022-02-13] * the whole document * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) G06N G01S G06V
A	SUN PEI ET AL: "Scalability in Perception for Autonomous Driving: Waymo Open Dataset", 2020 IEEE/CVF CONFERENCE ON COMPUTER VISION AND PATTERN RECOGNITION (CVPR), IEEE, 13 June 2020 (2020-06-13), pages 2443-2451, XP033805237, DOI: 10.1109/CVPR42600.2020.00252 [retrieved on 2020-08-03] * figure Figure 1 * ----- -/--	1-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 May 2024	Mariani, Giovanni

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& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application Number
EP 23 21 2958

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2019/069859 A1 (CAO PEIYAN [CN] ET AL) 7 March 2019 (2019-03-07) * paragraphs [0030] - [0040], [0088] - [0092]; figures 9-13 *	1-15	
A	EP 2 405 260 A1 (ALTA LAB S R L [IT]; YOUTECH S R L [IT]; POZZI PIETRO [IT]) 11 January 2012 (2012-01-11) * paragraphs [0003] - [0008], [0045] - [0058], [0082], [0105] - [0121], [0152] - [0157], [0191] - [0196], [0211] - [0213] *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 May 2024	Mariani, Giovanni

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X : particularly relevant if taken alone
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019069859 A1	07-03-2019	CN 110022770 A	16-07-2019
		EP 3547919 A1	09-10-2019
		TW 201832728 A	16-09-2018
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EP 2405260 A1	11-01-2012	DK 2405260 T3	11-08-2014
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		ES 2487940 T3	25-08-2014
		IT 1405995 B1	06-02-2014
		PL 2405260 T3	31-10-2014

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